3.0 DESCRIPTION OF THE NOAA KLM SENSOR PACKAGE

This section describes the characteristics of the NOAA KLM series instruments. The normal suite of instruments onboard the NOAA KLM series includes the following instruments: AVHRR/3, HIRS/3, AMSU-A and -B, SEM-2, DCS/2, SARSAT and sometimes SBUV/2. A detailed description of each instrument is provided in the respective subsections shown below. The instrument descriptions contain information such as spectral channel characteristics, system performance characteristics and additional information on the modules or subsystems that comprise the instrument. Table 1.2.1.3-1 provides a list of which sensors will be flown onboard which NOAA KLM spacecraft.

3.1 ADVANCED VERY HIGH RESOLUTION RADIOMETER/3 (AVHRR/3)

3.1.1 INSTRUMENT OPERATION

This section describes the six channel Advanced Very High Resolution Radiometer (AVHRR/3) developed by ITT-A/CD. The AVHRR/3 is used as the meteorological imaging system of the NOAA KLM spacecraft.

The AVHRR/3 is an imaging system in which a small field of view (1.3 milliradians by 1.3 milliradians) is scanned across the earth from one horizon to the other by continuous 360 degree rotation of a flat scanning mirror. The orientation of the scan lines are perpendicular to the spacecraft orbit track and the speed of rotation of the scan mirror is selected so that adjacent scan lines are contiguous at the subsatellite (nadir) position. Complete strip maps of the earth from pole to pole are thus obtained as the spacecraft travels in orbit at an altitude of approximately 833 km (450 n. miles). The analog data output from the sensors is digitized on board the satellite at a rate of 39,936 samples per second per channel. Each sample step corresponds to an angle of scanner rotation of 0.95 milliradians. At this sampling rate, there are 1.362 samples per IFOV. A total of 2048 samples will be obtained per channel per Earth scan, which will span an angle of ± 55.4 degrees from the nadir (subpoint view). All six spectral channels of the AVHRR/3 are registered so that they all measure energy from the same spot on the earth at the same time. All six channels are also calibrated so that the signal amplitude in each channel is a measure of the scene radiance. Although the AVHRR/3 has six channels, only five are transmitted to the ground at any one time. The radiometers are designed to operate within specification for a period of three years in orbit.

3.1.2 SYSTEM DESCRIPTION

3.1.2.1 General

The AVHRR/3 is a six channel scanning radiometer providing three solar channels in the visible-near infrared region and three thermal infrared channels. The AVHRR/3 has two one-micrometer wide channels between 10.3 and 12.5 micrometers. The instrument utilizes a 20.32 cm (8 inch) diameter collecting telescope of the reflective Cassegrain type. Cross-track scanning is accomplished by a continuously rotating mirror directly driven by a motor. The three thermal infrared detectors are cooled to 105 Kelvin (K) by a two-stage passive radiant cooler. A line synchronization signal from the scanner is sent to the spacecraft MIRP which in turn sends data sample pulses back to the AVHRR. Although AVHRR/3 is a six channel radiometer, only five channels are transmitted to the ground at any given time. Channels 3A and 3B cannot operate simultaneously. The data from the six channels are simultaneously sampled at a 40 kHz rate and converted to 10-bit binary form within the instrument. The data samples from each channel are output in a non-continuous burst of 10 space samples, 2048 Earth samples, and 10 internal

calibration target samples per scan.

A summary of the AVHRR/3 spectral characteristics and system performance characteristics are given in Tables 3.1.2.1-1 and 3.1.2.1-2, respectively.

Table 3.1.2.1-1. Summary of AVHRR/3 Spectral Channel Characteristics.						
Parameter	**Ch. 1**	**Ch. 2**	**Ch. 3A**	**Ch. 3B**	**Ch. 4**	**Ch. 5**
Spectral Range (micrometers)	0.58-0.68	.725-1.0	1.58-1.64	3.55-3.93	10.3-11.3	11.5-12.5
Detector type	Silicon	Silicon	InGaAs	InSb	HgCdTe	HgCdTe
Resolution (km)	1.09	1.09	1.09	1.09	1.09	1.09
IFOV* (milliradian)	1.3 sq.	1.3 sq.	1.3 sq.	1.3 sq.	1.3 sq.	1.3 sq.
S/N @ 0.5% albedo	$\geq$9:1	$\geq$9:1	$\geq$20:1	-	-	-
NEdT @ 300K	-	-	-	$\leq$.12K	$\leq$.12K	$\leq$.12K
MTF @ 1.09 km	>.30	>.30	>.30	>.30	>.30	>.30
Maximum Scene Temperature (K)	-	-	-	335	335	335
* Tolerance on IFOV values are $\pm$0.2 mr with a $\pm$0.1 mr design goal.						

Table 3.1.2.1-2. AVHRR/3 System Performance Characteristics.	
Parameter/Characteristic	**Value**
Telescope	8 in. diameter afocal Cassegrain
Scan Motor	360 rpm hysteresis - synchronous
Scan Mirror	8.25 in. x 11.6 in. Elliptical ribbed beryllium
Cooler	Two stage radiant cooler controlled @ 105 K
Data Output	10 bit parallel words
Video Sample Rate	40 kHz simultaneous sample of all channels
Output Data Rate	200 k word/sec max
Line Sync Pulse Out	100 microseconds @ 6 pps
Input Clock	0.9984 MHz

Overall Dimensions	31.33 in. X 14.35 in. X 11.5 in.
Weight	≤73 lbs.
Line to Line Scan Jitter	± 17 microseconds
Scan Sync Drift/24 hours	<3.0 microseconds
Calibration Accuracy	
- relative	≤1 NEdT
- absolute	Traceable to NIST
ICT monitor accuracy	0.1 degree C
Power	
Orbital Average	27W
Main Supply Bus Voltage	Nominal 28±0.56V (16-38V range)
Interface Bus Voltage	Nominal 10±0.5V (9-15V range)
Radiated EMI	
SAR Bands	-150 dBm
Instrument Temperature Range	
Operating	+10 to +30 degrees C
Storage	+5 to +30 degrees C
Survivable	-5 to +30 degrees C
Number of Telemetry channels	
Analog	22 channels (+0.2V to +5V)
Digital	15 channels (0V = "1", 5V = "0")
Commands	
Quantity	30
Amplitude	10 ± 0.7V
Duration	0.5 to 2.0 seconds
A/D Conversion	
Quantizing Level	10 bits
Accuracy (15 degrees C)	±1/2 LSB
Differential non-linearity (15 degrees C)	±1/2 LSB

Maximum Error (10 - 30 degrees C)	±1 LSB
Uncompensated Momentum	
Yaw Axis	0
Roll Axis	38 in-oz-sec, CCW, (+Y axis)
Pitch Axis	0
Maximum Angular Momentum	<0.268 Newton-m-sec
Data Sample Pulse from MIRP	
Duration	1.0 microsecond
Rate	39.936 kpps
Amplitude	5.0V
Electronic Calibration	
Ramp-Cal (during space view)	1024 levels
Volt-Cal (during earth scene)	3 levels

AVHRR/3 data is sampled only at specified times during the Earth scene and backscan regions of each scan period and not on a continuous basis.

Visible Channels 1, 2 and 3A have dual slope gain characteristics with slope intercepts as shown in Table 3.1.2.1-3.

Table 3.1.2.1-3. AVHRR/3 visible channel gain and intercept characteristics.		
Channel	**% Albedo**	**Counts**
1, 2	0-25% 26-100%	0-500 501-1023
3A	12.5% 12.6-100%	0-500 501-1023

The data from each of the five active channels is digitized in the radiometer to a 10-bit word and brought out of the instrument as a 10-bit parallel digital output to the spacecraft MIRP. In addition to these digital signals, the line synchronization signal is also routed to the MIRP on a separate buffer isolated line.

Some differences exist when switching between Channels 3A and 3B. The Channel 3A Select and Channel 3B Select commands are received and stored in a latching relay. A set of contacts in this relay is used to indicate the relay status virtually instantaneously through the digital telemetry. The second set of contacts in the relay switches a logic level on the A/D logic board, which, in turn, is used by the A/D sample and hold board to switch the A/D input between

Channel 3A and Channel 3B. This same logic level is also used by the 3A/3B select flag circuitry. Since the command relay is asynchronous, the data output will switch instantaneously between 3A or 3B, even if the scan is in the middle of a line. The select flag circuitry, however, operates differently.

When Channel 3B is selected, the patch temperature data is output every scan line (during the backscan), and every other scan line when 3A is selected. When switching from 3B to 3A, the zero volt marker between lines 5 and 6 indicates that they switched sometime during line 4. Therefore, there is one scan line of uncertainty when switching from 3B to 3A. When switching from 3A to 3B, the presence of patch temperature data between lines 11 and 12 indicates that the switch occurred sometime between lines 9 and 12. Therefore, there are two scan lines of uncertainty when switching from 3A to 3B.

The AVHRR/3 is comprised of five modules which are assembled together into a single unit instrument. These modules are:
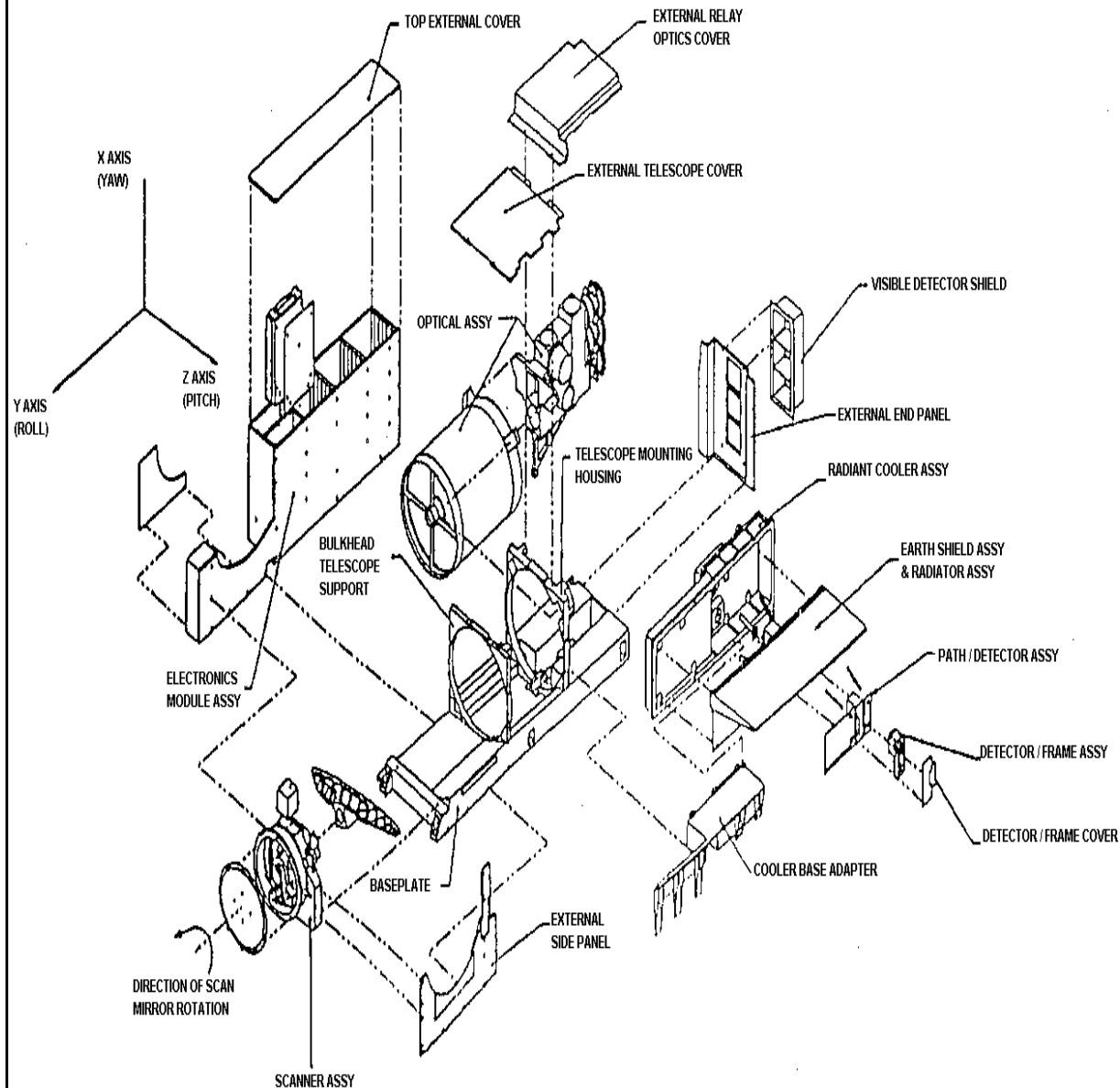
o   Scanner Module
o   Electronics Module
o   Radiant Cooler Module
o   Optical Subsystem
o   Baseplate Unit

An exploded view of the AVHRR/3 is shown in Figure 3.1.2.1-1.

3.1.2.2   Scanner Module

This module includes the scan motor, the mirror, and the scan motor housing. The scan motor is an 80 pole hysteresis synchronous motor. The motor has two power modes of operation and is normally operated in the high-power mode (~4.5 watts) in orbit in order to minimize scan line jitter. The scanner housing is an integral part of the motor and is made of beryllium. The scan mirror is also made of beryllium and is ~29.5 cm (11.6 inches) across the major axis and 20.96 cm (8.25 inches) across the minor axis. The scan motor rotates the mirror at 360 rpm to produce a contiguous scan of the Earth scene. The line-to-line jitter is less than ±17 microseconds. See Appendix J.1 for specific scan parameters and patterns of the AVHRR/3 instrument.

Figure 3.1.2.1-1. AVHRR/3 Exploded View.

TOP EXTERNAL COVER

EXTERNAL RELAY
OPTICS COVER

X AXIS
(YAW)

EXTERNAL TELESCOPE COVER

VISIBLE DETECTOR SHIELD

OPTICAL ASSY

Z AXIS
(PITCH)

Y AXIS
(ROLL)

EXTERNAL END PANEL

TELESCOPE MOUNTING
HOUSING

RADIANT COOLER ASSY

BULKHEAD
TELESCOPE
SUPPORT

EARTH SHIELD ASSY
& RADIATOR ASSY

ELECTRONICS
MODULE ASSY

PATH / DETECTOR ASSY

DETECTOR / FRAME ASSY

DETECTOR / FRAME COVER

COOLER BASE ADAPTER

BASEPLATE

EXTERNAL
SIDE PANEL

DIRECTION OF SCAN
MIRROR ROTATION

SCANNER ASSY

3.1.2.3   Electronics Module

The electronics module is in two sections, both of which bolt onto the instruments' inboard side panel. The curved box (Reference Figure 3.1.2.1-1) is the motor power supply. Thirty electronic circuit assemblies are used to make up the electrical system of the AVHRR/3. Twenty-two of these are located in the electronics box. The preamplifiers for Channels 1, 2, and

3A are located on the relay optics assembly. The IR Channel 4 and Channel 5 preamplifiers are located on the optics side of the electronics box. Channel 3B preamplifier is located near the 3B detector on the radiant cooler. Channels 4 and 5 preamplifier modules are accessible without the removal of the instrument from the spacecraft.

3.1.2.4 Radiant Cooler Module

The radiant cooler module is made up of four basic assemblies. These are (1) the cooler housing, (2) the first stage radiator, (3) the patch or second stage radiator and (4) the cooler cover. The first stage radiator is configured in such a manner as to shade most of its radiating area from the Earth by the cooler cover when the cover is deployed. A solenoid is used to deploy the cover. Once deployed, the cover cannot be closed. Mounted on the cold (105K) patch are the three thermal infrared detectors. The patch has a 144.5 cm^2 (22.4 in^2) radiating area.

Multi layer insulation thermally separates the first stage radiator from the housing, and the first stage optical window is thermally isolated and heated several degrees warmer than the 171 K radiator temperature to prevent condensation on it. During nominal operation the patch temperature is temperature controlled to 105 K.

3.1.2.5 Optical Subsystem

The optical subsystem consists of two subassemblies, a collecting telescope and a relay optics unit. The telescope is a 20.3 cm (8.0 inch) diameter aperture, reflective Cassegrain of a focal design (collimated output). The relay optics split the telescope exit beam into six discrete spectral bands and focus them onto their respective field stops. The spectral bands are:

- ○ Channel 1: 0.58 to 0.68 micrometers
- ○ Channel 2: 0.725 to 1.00 micrometers
- ○ Channel 3A: 1.58 to 1.64 micrometers
- ○ Channel 3B: 3.55 to 3.93 micrometers
- ○ Channel 4: 10.3 to 11.3 micrometers
- ○ Channel 5: 11.5 to 12.5 micrometers

The instantaneous field of view is 1.3 by 1.3 milliradians in all channels and is defined by an aperture plate in Channels 1, 2, and 3A and by the detector active areas in Channels 3B, 4, and 5. In addition, the optical subsystem has been designed to meet the total system MTF requirements with the detectors laterally displaced for channel-to-channel registration.

Polarization effects have been minimized in Channels 1, 2, and 3A by passing the optical beam transmitted by the first visible/infrared beamsplitter through a second beamsplitter of the same type which is oriented so as to compensate for polarization introduced by the first beamsplitter.

3.1.2.6 Baseplate Unit

The baseplate unit is the common structure to which all other modules are secured. Dowel pins are used to establish and maintain alignment of the scanner and optics modules. Alignment of the cooler to the optics is established by shims.

3.1.3 MIRP PROCESSING

This section is provided as an overview of the AVHRR/3 data processing that takes place in the Spacecraft Manipulated Information Rate Processor (MIRP). The MIRP sends a data sample pulse to the AVHRR/3 digital output timing logic which results in the sequential transfer of a data word for each radiometric channel. The MIRP processes these data into the following four outputs.

3.1.3.1 Automatic Picture Transmission (APT)

Any two of the six AVHRR/3 channels can be command-selected for processing. This data undergoes the following:

(a)   Resolution reduction by using every third scan line of AHVRR data.

(b)   Geometric correction to reduce the perspective effect due to the Earth's curvature and the satellite altitude. Details are contained in Section 4.2.

(c)   Digital to Analog - The digitally processed APT data are converted to a 2080 Hz bandwidth analog signal, amplitude modulated onto a 2.4 kHz carrier, and bandwidth limited to 4160 Hz in preparation for transmission by the VHF transmitters.

3.1.3.2 Global Area Coverage (GAC)

MIRP produces the GAC output by combining processed AVHRR/3 data with the TIP data. The GAC frame rate is 2 frames per sec; that is, it is one third of the AVHRR/3 frame rate. The GAC processing of the AVHRR/3 data makes the frame rates directly compatible by only using the data from every third AVHRR/3 scan. The MIRP further reduces the data by averaging the value of four adjacent samples and skipping one sample of each channel of AVHRR data across each scan line used. The TIP word and frame rate is directly compatible with the GAC word and frame rate; five TIP minor frames are inserted (at 0.1 seconds per frame) into the GAC frame each 0.5 seconds. Two parity bits are added to the 8-bit TIP word to form the 10-bit GAC word. The GAC output is supplied only to the spacecraft DTR Input Selector Unit of the XSU, and it is, therefore, not available for direct readout users.

3.1.3.3 High Resolution Picture Transmission (HRPT)

MIRP produces the HRPT and the LAC outputs by combining unprocessed AVHRR/3 data with TIP data. The basic frame rate and data rate of the HRPT is compatible with the AVHRR/3. Therefore, only buffering is required to construct the HRPT frame from the AVHRR/3 data. However, since the TIP frame rate is only one third that required to fill the HRPT frame, the TIP data must be repeated three times. This is accomplished by repeating the five TIP minor frames (104 words each) in each of three HRPT frames. As in GAC, two parity bits are added to the 8-bit TIP word to form the 10-bit MIRP word. The HRPT output is supplied to the S-band transmitter input control for real-time transmission.

3.1.3.4 Local Area Cover (LAC)

LAC is, by definition, recorded HRPT; thus, the LAC output is supplied only to the spacecraft DTR input selector for recording.

**3.2	HIGH RESOLUTION INFRARED RADIATION SOUNDER (HIRS/3)**

3.2.1	INSTRUMENT OPERATION

The High Resolution Infrared Radiation Sounder (HIRS/3) is a discrete stepping, line-scan instrument designed to measure scene radiance in 20 spectral bands to permit the calculation of the vertical temperature profile from Earth's surface to about 40 km.

Multispectral data from one visible channel (0.69 micrometers), seven shortwave channels (3.7 to 4.6 micrometers) and twelve longwave channels (6.5 to 15 micrometers) are obtained from a single telescope and a rotating filter wheel containing twenty individual filters. An elliptical scan mirror provides cross-track scanning of 56 increments of 1.8 degrees. The mirror steps rapidly (<35 msec), then holds at each position while the 20 filter segments are sampled. This action takes place each 100 msec. The instantaneous FOV for each channel is approximately 1.4 degrees in the visible and shortwave IR and 1.3 degrees in the longwave IR band which, from an altitude of 833 kilometers, encompasses an area of 20.3 kilometers and 18.9 kilometers in diameter, respectively, at nadir on the Earth.

Three detectors are used to sense the radiation. A silicon photodiode at the instrument temperature (nominally 15 degrees C) detects the visible energy. An Indium Antimonide detector and a Mercury Cadmium Telluride detector (mounted on a passive radiator and operating at 100 K) sense the shortwave and longwave IR energy. The shortwave and visible optical paths have a common field stop, while the longwave path has an identical but separate field stop. Registration of the fields of view in all channels is largely determined by these stops with secondary effects from detector position.

IR Calibration of the HIRS/3 is provided by programmed views of two radiometric targets: a warm target mounted to the instrument base and a view of space. Data from these views provides sensitivity calibrations for each channel every 40 lines (256 seconds), if commanded. Internally generated electronic signals provide calibration and stability monitoring of the amplifier and readout electronics.

Data from the instrument is multiplexed into a single data stream controlled by the TIP system of the spacecraft. Information from the radiometric channels and voltage telemetry are converted to 13-bit binary data. Radiometric information is processed to produce the maximum dynamic range such that instrument and digitizing noises are a small portion of the signal output. Each channel is characterized by a noise equivalent radiance (NEΔN) and a set of calibration data that may be used to derive atmospheric temperatures and probable errors.

The HIRS/3 instrument is a single package mounted on the Instrument Mounting Platform (IMP) of the NOAA KLM spacecraft. Thermal blankets cover most outer surfaces other than that of the radiating panel and door area. The cooler radiating surface views space, emitting its heat to provide passive radiant cooling of the shortwave and longwave detectors to the stabilized 100K operating temperature. An Earth shield on the cooler door assembly insulates the door from Earth direction thermal input. The door is closed during launch and through the initial orbital outgas period (at least 14 days). After this outgas period, the door is opened permanently for cooling of the radiator. If there are indications of contaminate accumulation subsequently, a door-open outgas procedure can be performed by applying power to the heaters located on both stages of the radiant cooler. During this procedure, the cooler temperature rises to approximately 300 K.

Table 3.2.1-1 lists the system characteristics of the HIRS/3 Instrument. Table 3.2.1-2 lists the

spectral channel and sensitivity requirements for the HIRS/3. See Appendix J.2 for specific scan parameters and patterns of the HIRS/3 instrument.

Table 3.2.1-1. HIRS/3 System Characteristics.	
Characteristic	**Value**
Optical Field of View	1.4 degrees VIS/SW IR 1.3 degrees LW IR
Included Energy	98% within 1.80 degrees
Channel to channel registration	LW: <1.5% of 1.8 degrees Step size SW: <1% of Ch. 19 FOV FWHM
Earth Scan Angle	±49.5 degrees from nadir
Earth Scan Steps	56 increments of 1.8 degrees
Step and Dwell Time	100 msec total
Retrace Steps	8
Total Scan plus Retrace Time	6.4 seconds
Earth Swath coverage	1127 km

Earth Field Coverage:
  (SW IR) + VIS
  (LW IR)
	20.3 km (1.4 degrees IFOV) at nadir
	18.9 km (1.3 degrees IFOV) at nadir

Radiometric Calibration	290 K IWT Blackbody and Space Look
Frequency of Radiometric Calibration	256 seconds, typical
Dwell Time at Calibration Position	5.6 seconds at IWT, 4.8 seconds at space
Longwave Channels	12 (6.5 to 15 micrometers)
Longwave Detector	Mercury Cadmium Telluride
Shortwave Channels	7 (3.7 to 4.6 micrometers)
Shortwave Detector	Indium Antimonide
IR Detectors Temperature	100 K
Visible Channel	1 (0.69 micrometers)
Visible Detector	Silicon
Visible Detector Temperature	Ambient
Signal Quantizing Levels	8192 (13 bit coding)
Electronic Calibration	32 equal levels each polarity

Frequency of Electronic Calibration	One level each scan line
Telescope Aperture	15.0 cm (5.9 in)
Filter Housing Temperature	290 K (with baseplate at 283 K)

Channel Number	Central Wavenumber (cm⁻¹)	Wavelength (micrometers)	Half Power Bandwidth (cm⁻¹)	Noise Equivalent Delta Radiance (NEΔN) mW/(m²-sr-cm⁻¹)
1	669	14.95	3	3.00
2	680	14.71	10	0.67
3	690	14.49	12	0.50
4	703	14.22	16	0.31
5	716	13.97	16	0.21
6	733	13.64	16	0.24
7	749	13.35	16	0.20
8	900	11.11	35	0.10
9	1,030	9.71	25	0.15
10	802	12.47	16	0.15
11	1.365	7.33	40	0.20
12	1,533	6.52	55	0.20
13	2,188	4.57	23	0.006
14	2,210	4.52	23	0.003
15	2,235	4.47	23	0.004
16	2,245	4.45	23	0.004
17	2,420	4.13	28	0.002
18	2,515	4.00	35	0.002
19	2,660	3.76	100	0.001
20*	14,500	0.690	1,000	0.10% albedo

Table 3.2.1-2. HIRS/3 Spectral Characteristics.

*Visible Channel

3.2.2   SYSTEM DESCRIPTION

3.2.2.1   Introduction

The HIRS/3 is a 20-channel scanning radiometric sounder utilizing a stepping mirror to accomplish cross-track scanning, directing the radiant energy from the Earth to a single, 15.24 cm (6-inch) diameter telescope assembly every tenth of a second. Collected energy is separated by a beamsplitter into longwave (above 6.5 micrometers) and shortwave (visible to 4.6 micrometers), passed through field stops and through a rotating filter wheel to cooled detectors. In the shortwave path, a second beamsplitter separates the visible channel to a silicon detector.

The scan logic and control set the sequence of Earth viewing steps to provide a rapid scan mirror step motion to 56 fixed positions for spectral sampling of each respective air column. The filter wheel rotation is synchronized to this step and hold sequence, with approximately one-third of the wheel blank to accommodate each step interval and with the filters positioned for sampling only after the mirror has reached the hold position. Registration of the optical fields for each channel to a given column of air is dependent to some degree on spacecraft motion and on the alignment of two field stops, which can be adjusted to reduce registration error to less than 1 percent of the field diameter.

The characteristics of the instrument temperature sensors are shown in Table 3.2.2.1-1, where it may be noted that calibration sources are measured very precisely.

Table 3.2.2.1-1. HIRS/3 Sensor Temperature Ranges.				
Channel Sensor Location	Subcomm Analog (K)	Digital "A" (K)	Approx. Digital "A" Sensitivity (Counts/K)	Nominal @ Operating Temperature
Patch - full range	90-320	90-320	53	@100K
Patch - expanded range		90-150	141	@100K
Radiator	150-320	150-320	60	@170K
Filter Wheel (F/W) Motor	260-320	260-320	71	@300K
Scan Motor	260-320*	260-320	78	@295K
Baseplate	260-320*	260-320	78	@290K
Electronics	260-320	260-320	78	@290K
Primary Mirror		260-320	78	@290K
Secondary Mirror		260-320	78	@290K
Scan Mirror		260-320	78	@290K
F/W Housing (HSG) - 1		273.15K-333.15K	152	@295K

F/W Housing (HSG) - 2		273.15K-333.15K	152	@303K
F/W Housing (HSG) - 3		273.15K-333.15K	152	@295K
F/W Housing (HSG) - 4		273.15K-333.15K	152	@295K
Internal Warm Target (IWT) - 1		273.15K-333.15K	152	@290K
Internal Warm Target (IWT) - 2		273.15K-333.15K	152	@290K
Internal Warm Target (IWT) - 3		273.15K-333.15K	152	@290K
Internal Warm Target (IWT) - 4		273.15K-333.15K	152	@290K
Internal Cold Target (ICT) - 1		243.15K-303.15K	152	@273K
Internal Cold Target (ICT) - 2		243.15K-303.15K	152	@273K
Internal Cold Target (ICT) - 3		243.15K-303.15K	152	@273K
Internal Cold Target (ICT) - 4		243.15K-303.15K	152	@273K
* Housekeeping TLM (full time temperature monitoring on switched +28 VDC BUS)				

Radiant energy is focused on cooled detectors operating at a near optimum temperature of 100K. A Mercury Cadmium Telluride detector and an Indium Antimonide detector are mounted on a two-stage radiant cooler. This assembly is large enough to have reserve cooling capacity, permitting active thermal control to maintain the detectors fixed at 100K. A system of heating the patch and first stage is provided for initial outgassing and for decontamination later if it should be required.

Electronic circuits provide the functions of power conversion, command, telemetry, and signal processing. Amplification of the inherently weak signals from the detectors is done by low noise amplifiers. Radiant signals are fed through a base reference and memory processor, multiplexed, and A/D converted by a 13-bit range system. Once converted to a digital format, the data are again multiplexed with HIRS/3 "housekeeping" data and provided as a serial data stream at the digital A output. Data from HIRS/3 are held in memory until called by the TIP request signals and clocked out of the instrument by the TIP clock.

Repetitive inclusion of electronic calibration signals and the periodic command to scan to space and one internal blackbody provides the system with a complete set of data collection, calibration, and control that permits reliable operation in orbit.

3.2.2.2   Scan System Description

The heart of the scan system is a stepper motor with 200 steps per rotation. Assembled to the shaft of the stepper motor are (1) a scan mirror mounted with the mirror surface plane at 45 degrees with

respect to the axis of the motor shaft, (2) a DC torque motor, (3) a DC tachometer, (4) a shaft position encoder, and (5) a two contact slip ring assembly. The DC tachometer is used to derive rate information which is used to control a DC torque motor to aid stopping of the scan rotation as the scan settles into a track position or into a step position.

The drive control signals for the stepper motor are generated by a step generator which has input control features for retrotorque control, step/slew control and rotational direction control (up/down). Output from a scan regulator with power level control is applied to the motor driver to provide stepping torque levels as required.

The Scan Control logic utilizes timing signals and position commands in conjunction with position information derived from a position encoder to monitor and control performance of the system. Connections to a thermal sensor on the scan mirror are provided via two leads from the mirror through the hollow motor shaft to a slip ring assembly at the opposite end of the shaft.

3.2.3 CALIBRATION REQUIREMENTS

The Calibration Enable command enables the radiometric calibration control logic. Calibration is activated by the calibration start pulse (CSP) which occurs every 256 seconds. The CSP initiates a sequence of scans that provide radiometric calibration of the instrument. When the Calibration Disable command is in effect, the CSP will be ignored and the instrument will continue its normal scan sequence.

3.2.4 HIRS/3 DIGITAL A DATA

Digital A data is clocked into the spacecraft TIP whenever the "A_1" Data Enable Pulse is presented to the instrument. A full set of HIRS/3 operational data, including command status monitors, housekeeping information and radiance data of the 20 channels, is contained in the Digital A output. The HIRS/3 data repeats every 6.4 seconds as described below. The 6.4 second period contains 64 elements.

Digital A output is divided into "Elements" of 288 bits. One element is phased to fit into a TIP minor frame. The TIP will allocate 36 8-bit words to accommodate the HIRS/3 element. These TIP words will be grouped by two in fixed locations throughout the 100 millisecond minor frame.

Sixty-four elements make up each scan. The formats for the elements repeat every 6.4 seconds and correspond to the particular parts of the scan. Element number 0 through 55 are earth scan data (target data during the calibration sequence). Elements 56 through 63 are associated with retrace or when the mirror is slewing between positions. The elements are divided as follows:

Bits 1-26

Two 13 bit words have the same function in all 64 elements. The function assembled in these words are described in Table 3.2.4-1.

Table 3.2.4-1. Functions of Bits 1-26 in the HIRS/3 Elements.			
Word #	**Bits**	**Function**	**Range (Decimal)**
1	1-8	Scan Encoder Position	0 to 199
	9-13	Electronic Cal Level Indicator	0 to 31

2	1 - 6	Channel 1 Period Monitor	0 to 63
	7-12	Element Number	0 to 63
	13	Filter Sync Designator	n/a

Bits 27-286

This group of bits are divided into 20 13-bit words. The word functions are dependent on element number. These functions are given in Table 3.2.4-2. Except for the two status words in Element 63, all words are quantity where bit 1 is the sign bit and bits 2 through 13 are amplitude (0 to 4095). Bit 2 is the most significant bit (MSB) of quantity. The sign bit is: logic "1" is + and logic "0" is -.

Bits 287 and 288

In the same manner as for bits 1 through 26, these two bits have the same function in all 64 elements as shown in Table 3.2.4-2.

Table 3.2.4-2. Functions of Bits 287-288 in the HIRS/3 Elements.		
Bits	**Function**	**Remarks**
287	Valid Data Bit	logic "1" Valid Data logic "0" Ignore Radiometric Data
288	Odd Bit Parity	n/a

One HIRS/3 word is contained in two contiguous 8-bit TIP words. These two words occur in 1.899 msec. Eighteen pairs, each consisting of two Minor Frames TIP words, are required per minor frame. These eighteen words make up one HIRS/3 Element. The Digital A output is a serial output of 288 bits per element. The first bit (Bit 1) occurs in the MSB of TIP word 14.

Tables 3.2.4-3 and 3.2.4-4 contain the HIRS/3 Digital A Radiometric and housekeeping functions, and the Digital A Status Telemetry, respectively.

Table 3.2.4-3. HIRS/3 Digital A Radiometric and Housekeeping Functions.			
Element #	**Bit #**	**Function**	**Remarks**
0 - 55	27-39	Radiometric Channel No. 1 (668.5 cm^{-1})	0 counts radiance from scene equal radiance from Filter Wheel (FW). Minus (-) values are colder than FW. Plus (+) values are warmer than FW.
	40-52	Radiometric Channel No. 17 (2,420 cm^{-1})	0 counts offset from FW radiance. Plus and minus are hotter and cooler than offset.
	53-65	Radiometric Channel No. 2 (680 cm^{-1})	No offset.

	66-78	Radiometric Channel No. 3 (690 cm^{-1})	No offset.
	79-91	Radiometric Channel No. 13 (2,188 cm^{-1})	Offset.
	92-104	Radiometric Channel No. 4 (703 cm^{-1})	No offset.
	105-117	Radiometric Channel No. 18 (2515 cm^{-1})	Offset.
	118-130	Radiometric Channel No. 11 (1365 cm^{-1})	No offset.
	131-143	Radiometric Channel No. 19 (2,660 cm^{-1})	Offset.
	144-156	Radiometric Channel No. 17 (749 cm^{-1})	No offset.
	157-169	Radiometric Channel No. 8 (900 cm^{-1})	No offset.
	170-182	Radiometric Channel No. 20 Visible (14,500 cm^{-1})	Black is minus. White is plus.
	183-195	Radiometric Channel No. 10 (802 cm^{-1})	No offset.
	196-208	Radiometric Channel No. 14 (2,210 cm^{-1})	Offset.
	209-221	Radiometric Channel No. 6 (749 cm^{-1})	No offset.
	222-234	Radiometric Channel No. 5 (716 cm^{-1})	No offset.
	235-247	Radiometric Channel No. 15 (2,235 cm^{-1})	Offset.
	248-260	Radiometric Channel No. 12 (1,533 cm^{-1})	No offset.
	261-273	Radiometric Channel No. 16 (2,245 cm^{-1})	Offset.
	274-286	Radiometric Channel No. 9 (1,030 cm^{-1})	Offset.

56	27-286	Positive Electronics Calibration applied to 20 radiometric channels.	Calibration level advances one of the 32 equal level steps on successive scans. The offset and gain of each channel will influence the amplitude of the signal. The calibration level applied to the (continued) electronic channels is indicated by bits 9 through 13 of the Element.
57	27-286	Negative Electronics Calibration applied to 20 radiometric channels.	Calibration level advances one of the 32 equal level steps on successive scans. The offset and gain of each channel will influence the amplitude of the signal. The calibration level applied to the (continued) electronic channels is indicated by bits 9 through 13 of the Element.
58	27-91	Internal Warm Target Temperature Sensor #1	Value repeated 5 times. Range 273 to 333 K.
	92-156	Temperature Sensor #2	Value repeated 5 times. Range 273 to 333 K.
	157-221	Temperature Sensor #3	Value repeated 5 times. Range 273 to 333 K.
	222-286	Temperature Sensor #4	Value repeated 5 times. Range 273 to 333 K.
59	27-91	Internal Cold Target Temperature Sensor #1	Value repeated 5 times. Range 243 to 303 K.
	92-156	Temperature Sensor #2	Value repeated 5 times. Range 243 to 303 K.
	157-221	Temperature Sensor #3	Value repeated 5 times. Range 243 to 303 K.
	222-286	Temperature Sensor #4	Value repeated 5 times. Range 243 to 303 K.
60	27-91	Filter Wheel Housing Temperature Sensor #1	Value repeated 5 times. Range 273 to 333K.
	92-156	Temperature Sensor #2	Value repeated 5 times. Range 243 to 303 K.
	157-221	Temperature Sensor #3	Value repeated 5 times. Range 243 to 303 K.

	221-286	Temperature Sensor #4	Value repeated 5 times. Range 243 to 303 K.
61	27-91	Patch Temperature Expanded Scale	Value repeated 5 times. Range 90 to 150 K.
	92-156	First Stage Radiator Temperature Sensor	Value repeated 5 times. Range 150 to 320 K.
	157-221	Filter Wheel Housing Heater Current	Value repeated 5 times. Range 0 to 500 ma.
	222-286	Electronic Calibration Digital to Analog Converter	Value repeated 5 times. Range 0 to 4 V.
62	27-39	Scan Mirror Temperature	Range 260 to 320 K
	40-52	Primary Telescope Temperature	Range 260 to 320 K
	53-65	Secondary Telescope Temperature	Range 260 to 320 K
	66-78	HIRS/3 Baseplate Temperature	Range 260 to 320 K
	79-91	HIRS/3 Electronics Temperature	Range 260 to 320 K
	92-104	Patch Temperature - Full Range	Range 90 to 320 K
	105-117	Scan Motor Temperature	Range 260 to 320 K
	118-130	Filter Wheel Motor Temperature	Range 260 to 320 K
	131-143	Cooler Housing Temperature	Range 260 to 320 K
	144-156	Patch Control Power	Range 0 to 80 mw
	157-169	Scan Motor Current	Range 0.65 to 1.0 ma
	170-182	Filter Motor Current	Range 100 to 300 ma
	183-195	+15 VDC	Range 15 ± 0.2 V
	196-208	-15 VDC	Range -15 ± 0.2 V
	209-221	+7.5 VDC	Range +7.5 ± 0.05V
	222-234	-7.5 VDC	Range -7.5 ± 0.05V
	235-247	+10 VDC	Range 10 ± 0.2V
	248-260	+5 VDC	Range 5 ±0.2V
	261-273	Analog Ground	Range 1 count

	274-286	Analog Ground	Range ± 1 count
63	27-39	Line Counter (Gives the number of lines from the last auto calibration sequence)	0 to 8191 (There is no sign bit used in the line counter). Reset to 0 counts is only when counter overflows.
	40-52	First Status Word	First 5 bits are instrument serial number (no sign bit). The remaining bits indicate status as shown in Table 3.2.4-3.
	53-65	Second Status Word	First 5 bits are zero fill. The remaining bits indicate status as shown in Table 3.2.4-3.
	66-78	Data Verification Binary Code	Binary code is: (1 1 1 1 0 0 1 0 0 0 1 1) Equivalent base10 value: +3875
	79-91		Base 10 value: +1443
	92-104		Base 10 value: -1522
	105-117		Base 10 value: -1882
	118-130		Base 10 value: -1631
	131-143		Base 10 value: -1141
	144-156		Base 10 value: +1125
	157-169		Base 10 value: +3655
	170-182		Base 10 value: -2886
	183-195		Base 10 value: -3044
	196-208		Base 10 value: -3764
	209-221		Base 10 value: -3262
	222-234		Base 10 value: -2283
	235-247		Base 10 value: -2251
	248-260		Base 10 value: +3214
	261-273		Base 10 value: +1676
	274-286		Base 10 value: +1992

Table 3.2.4-4. HIRS/3 Digital A Status Telemetry.			
Element #	**Bit #**	**Function**	**Logic State**

First Status Word				
63	45	Instrument ON/OFF	ON=1	
	46	Scan Motor ON/OFF	ON=0	
	47	Filter Wheel ON/OFF	ON=0	
	48	Electronics ON/OFF	ON=1	
	49	Cooler Heat ON/OFF	ON=0	
	50	Internal Warm Target Position	True=0	
	51	Internal Cold Target Position	True=0	
	52	Space Position	True=0	
Second Status Word				
63	58	Nadir position	True=0	
	59	Calibration Enable/Disable	Enabled=0	
	60	Cooler Door Release Enable/Disable	Enabled=0	
	61	Cooler Door Open	Yes=1	
	62	Cooler Door Closed	Yes=1	
	63	Filter Housing Heat ON/OFF	ON=0	
	64	Patch Temperature Control ON/OFF	ON=0	
	65	Filter Motor Power HIGH	Normal=1	

3.3   ADVANCED MICROWAVE SOUNDING UNIT-A (AMSU-A)

3.3.1   INSTRUMENT OPERATION

The Advanced Microwave Sounding Unit-A (AMSU-A) system is implemented in two separate modules: the AMSU-A1 and AMSU-A2. The AMSU-A is a multi-channel microwave radiometer that will be used for measuring global atmospheric temperature profiles and will provide information on atmospheric water in all of its forms (with the exception of small ice particles, which are transparent at microwave frequencies) from the NOAA KLM spacecraft.

AMSU-A is a cross-track, line-scanned instrument designed to measure scene radiances in 15 discrete frequency channels which permit the calculation of the vertical temperature profile from about 3 millibars (45 km) pressure height to the Earth's surface. At each channel frequency, the antenna beamwidth is a constant 3.3 degrees (at the half power point). Thirty contiguous scene resolution cells are sampled in a stepped-scan fashion every eight seconds, each scan covering 50 degrees on each side of the subsatellite path. These scan patterns and geometric resolution translate to a 50 km diameter cell at nadir and a 2,343 km swath width from the 833 km nominal orbital altitude.

3.3.2   SYSTEM DESCRIPTION

3.3.2.1   <u>General</u>

Hardware for the two lowest frequencies is located in one module (AMSU-A2) and that for the remaining thirteen frequencies in the second module (AMSU-A1). This arrangement puts the two lower atmospheric moisture viewing channels into one module and the oxygen absorption channels into a second common module to ensure commonality of viewing angle independent of any module and/or spacecraft misalignment due to structural or thermal distortions. The AMSU-A1's concept of multiplexing thirteen frequencies in this second module is provided by a two-antenna system. This multiplexing approach provides minimum front-end RF loss and a constant 3.3 degree antenna beamwidth with greater than 95 percent beam efficiency. The radiometer characteristics of the AMSU-A channels are summarized in Table 3.3.2.1-1.

AMSU-A1 consists of 12 V-band channels (3 through 14) and one W-band channel (15) and associated circuitry. This module provides a complete and accurate vertical temperature profile of the atmosphere from the Earth's surface to a height of approximately 45 km.

AMSU-A2 contains the two lower frequencies (K-band channel 1 and Ka-band channel 2), and the associated scanning, calibration, processing, and power control hardware and circuitry. This module is used to study atmospheric water in all of its forms with the exception of small ice particles.

AMSU-A is configured in the following major subsystems: Antenna/Drive/Calibration Subsystem; Receiver Subsystem; Signal Processor Subsystem and Structural/Thermal Subsystem.
The AMSU microwave radiometers are heterodyne receivers, where the received radio frequency (RF) is downconverted to a lower intermediate frequency (IF). The relationship between the RF and IF signals is shown in Figure 3.3.2.1-1.
Given the IF filter band edge frequencies, f_1 and f_2, and the central frequency, f_0, the frequency response of a channel can be fully characterized (assuming unity response for all channels).

For the AMSU instruments, there are three types of channels:

      1.   Single passband channels (AMSU-A 1-4, 6-9, 15; and AMSU-B 16,17),

2.   Double sideband channels (AMSU-A 5, 10; and AMSU-B 18-20), and

3.   Quadruple sideband channels (AMSU-A 11-14).

Figure 3.3.2.1-1. Frequency translation of a broadband signal in heterodyne reception. Adapted from Figure 1.9b in "Atmospheric Remote Sensing by Microwave Radiometry," M. Janssen ed., John Wiley, 1993.
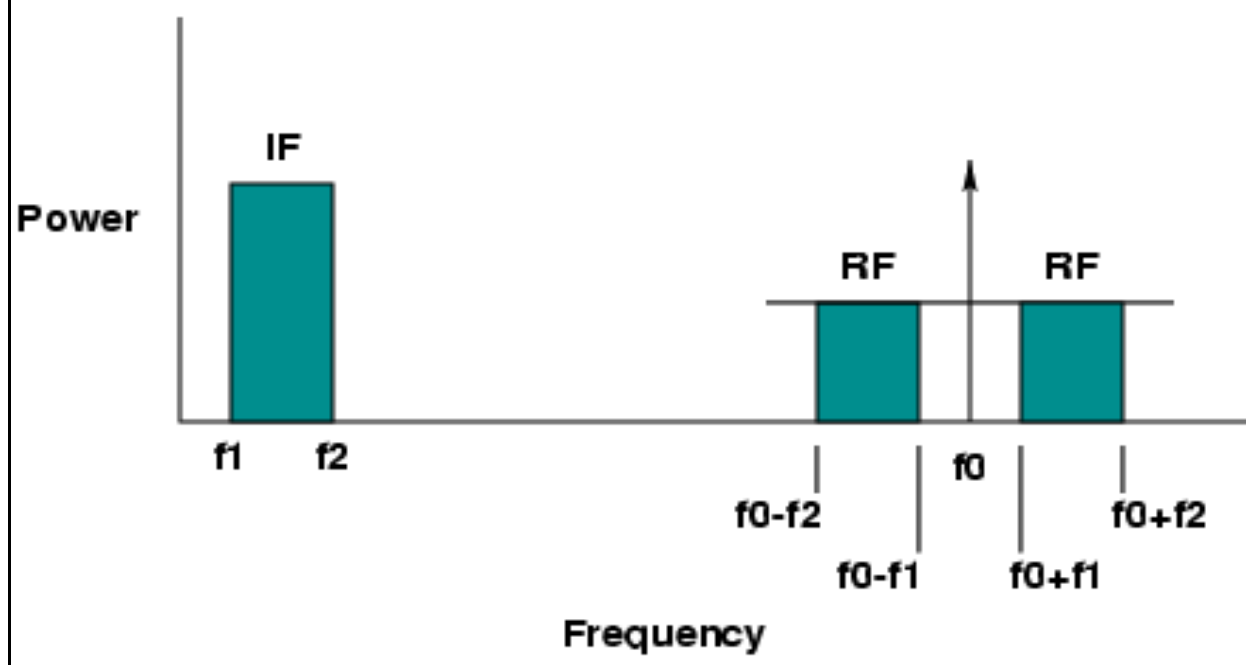
Single passband channels can be defined as those whose bandwidth span the channel central frequency, as shown in Figure 3.3.2.1-2. Typically for these channels, stopbands are specified to reduce the effects of local oscillator noise (source of the central frequency signal). The frequency range for these channels can be expressed as:

$$f_0 - SHW - HW \rightarrow f_0 - SHW \qquad (3.3.2.1-1)$$

and

$$f_0 + SHW \rightarrow f_0 + SHW + HW \qquad (3.3.2.1-2)$$

to exclude the stopband frequencies. Comparison to Figure 3.3.2.1-1 would give:

$$f_1 \equiv SHW \text{ and } f_2 \equiv SHW + HW \qquad (3.3.2.1-3)$$

For those AMSU channels that have relatively narrow stopbands (channels1-4, 6-9; around 18MHz) the difference between calculating Planck radiances using the frequency response shown in equations 3.3.2.1-1 and 3.3.2.1-2 and a simple $f_0 - HW \rightarrow f_0 + HW$ is a fraction of a

thousandth of a degree. Note for AMSU channels 15-17, the stopband widths are about 800-1000 MHz and should always be considered.

Figure 3.3.2.1-2. Schematic illustration of a single passband channel. AMSU-A channels 1-4, 6-9, and 15; and AMSU-B channels 16 and 17 are considered single passband channels.
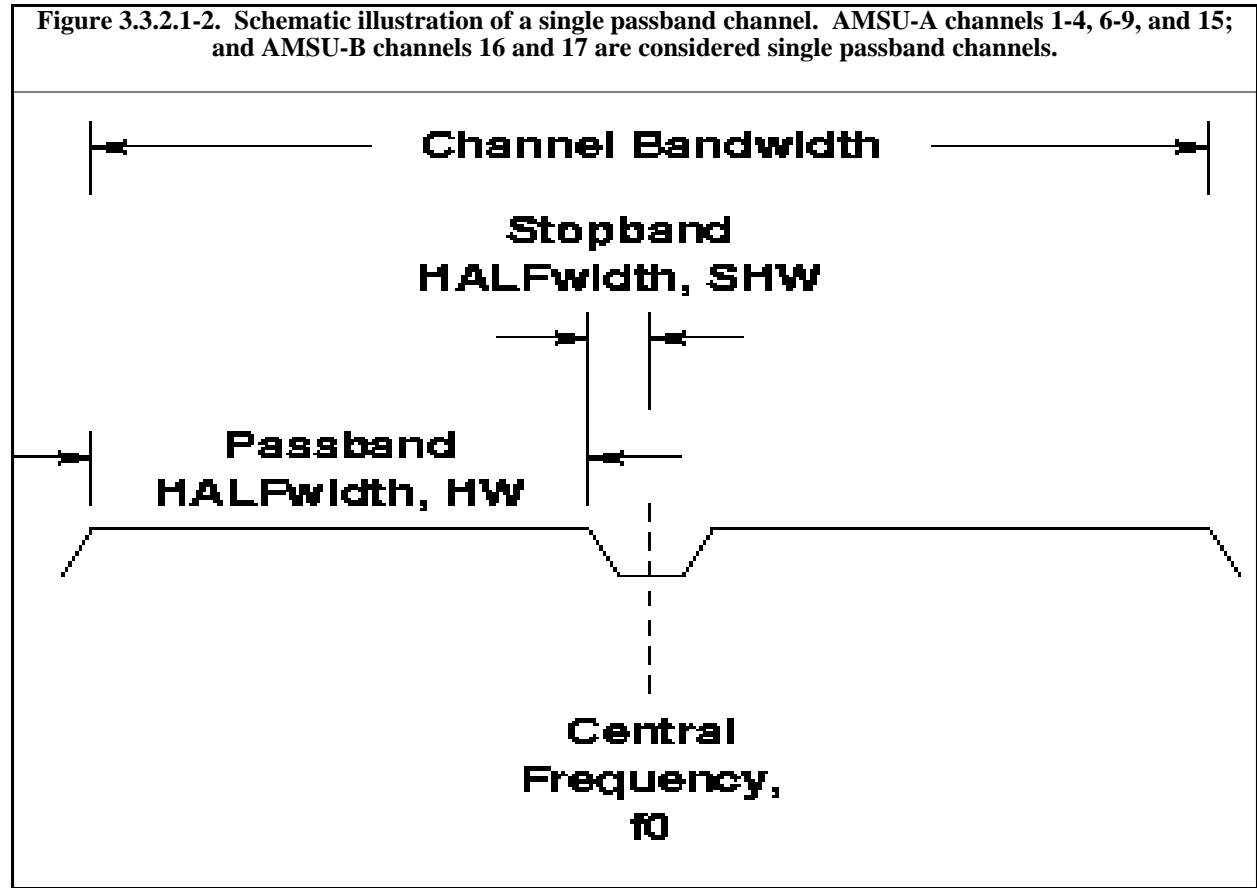
Double sideband channels are shown schematically in Figure 3.3.2.1-3. These channels are also referred to as folded passbands with the lower frequency sideband referred to as the lower sideband and the higher frequency sideband being the upper sideband. For these channels the frequency response of the lower sideband can be expressed as:

$$f_0 - df - HW \rightarrow f_0 - df + HW \qquad (3.3.2.1-4)$$

For the upper sideband, it can be expressed as:

$$f_0 + df - HW \rightarrow f_0 + df + HW \qquad (3.3.2.1-5)$$

Comparison to Figure 3.3.2.1-1 would give,

$$f_1 \equiv df - HW \quad and \quad f_2 \equiv df + HW \qquad (3.3.2.1-6)$$

where *df* is the offset to the *center* of the sideband.

Quadruple sideband channels are shown schematically in Figure 3.3.2.1-4. They resemble two double sideband "subchannels" on either side of the channel central frequency (Note: "subchannels" is not a common or rigorous term and is used here for explanation only).   For the lower "subchannels," the frequency response can be expressed as:

Figure 3.3.2.1-3. Schematic illustration of a double sideband channel. AMSU-A channels 5 and 10, and AMSU-B channels 18 - 20 are double sideband channels.
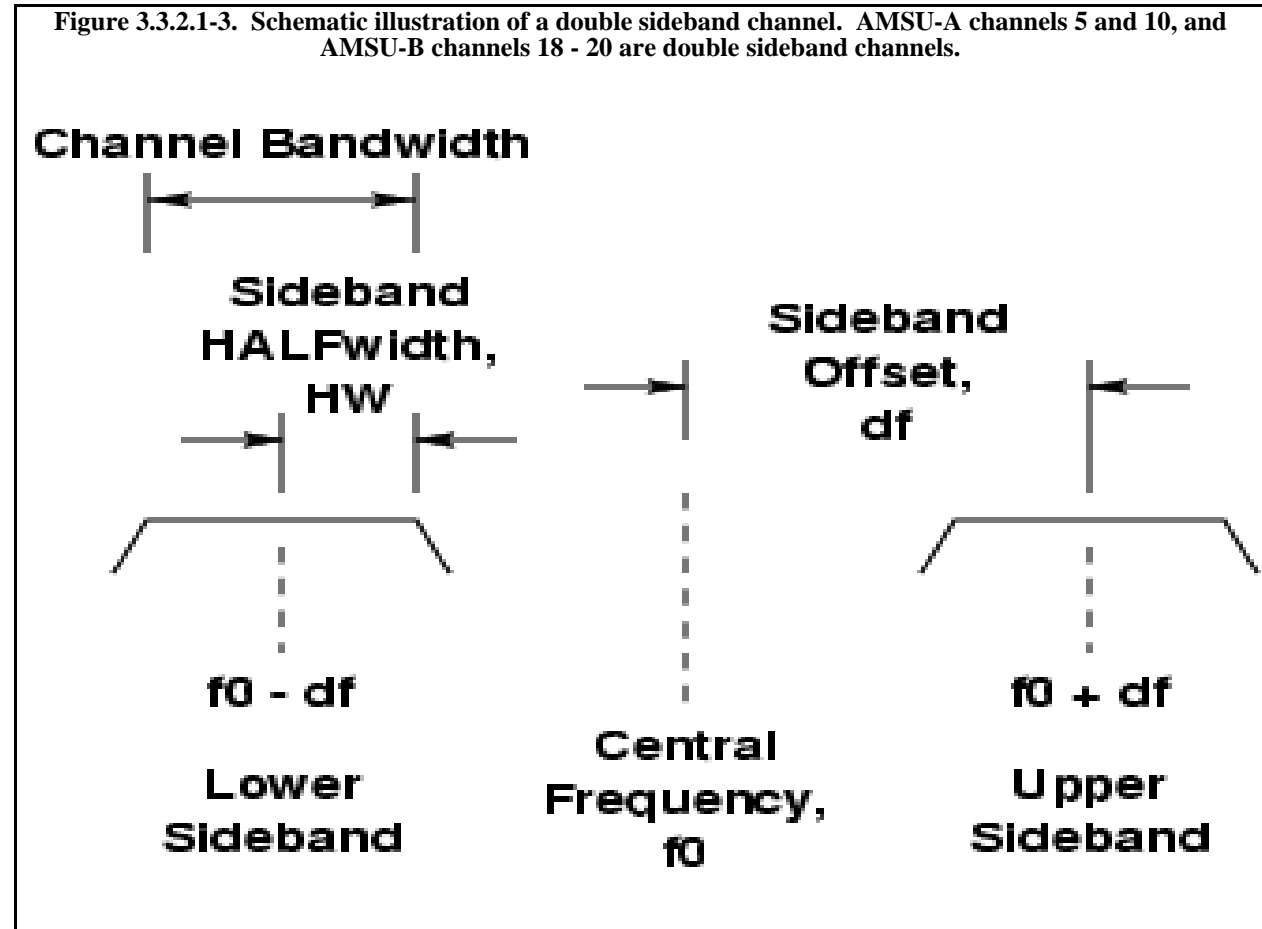
$$f_0 - df_1 - df_2 - UHW \rightarrow f_0 - df_1 - df_2 + UHW$$
$$and$$
$$f_0 - df_1 + df_2 - LHW \rightarrow f_0 - df_1 + df_2 + LHW$$

(3.3.2.1-7)

and for the upper "subchannels," the frequency response can be expressed as:

$$f_0 + df_1 - df_2 - LHW \rightarrow f_0 + df_1 - df_2 + LHW$$
$$and$$
$$f_0 + df_1 + df_2 - UHW \rightarrow f_0 + df_1 + df_2 + UHW$$

(3.3.2.1-8)

Comparison to Figure 3.3.2.1-1 gives four IF values. Two for the lower sideband:

$$f_1 \equiv df_1 - df_2 - LHW \text{ and } f_2 \equiv df_1 - df_2 + LHW \qquad \text{(3.3.2.1-9)}$$

and two for the upper sideband:

$$f_3 \equiv df_1 + df_2 - UHW \text{ and } f_4 \equiv df_1 + df_2 + UHW \qquad \text{(3.3.2.1-10)}$$

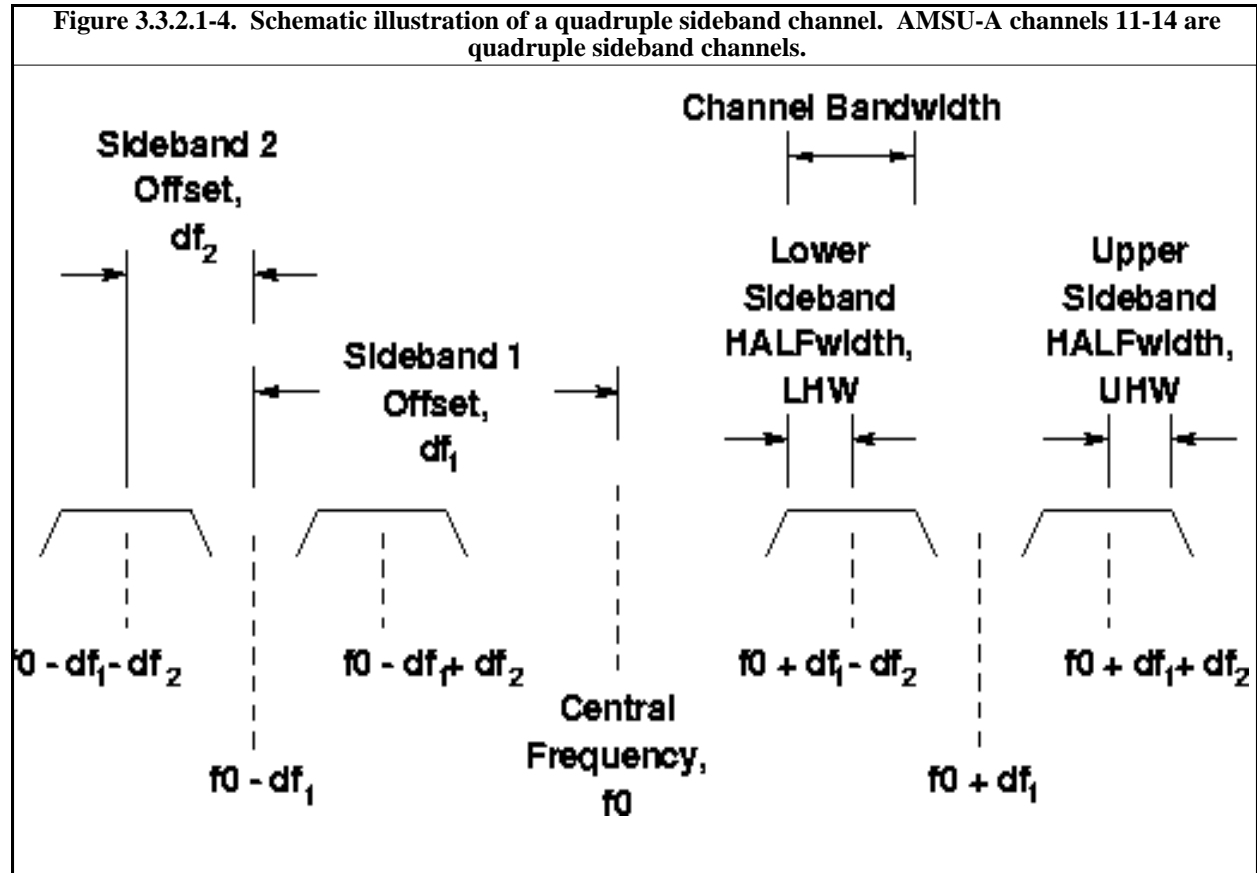where df_1 and df_2 are the offsets to the center of the sidebands.

Figure 3.3.2.1-4. Schematic illustration of a quadruple sideband channel. AMSU-A channels 11-14 are quadruple sideband channels.

Table 3.3.2.1-1. Channel Characteristics and Specifications of AMSU-A.							
Chan. #	Channel Frequency (MHz)	# bands	Nominal Bandwidth (MHz)	Nominal Beamwidth (degrees)	NEΔT (K) (Spec.)	Polarization at nadir [1]	Instrument Component
1	23,800	1	270	3.3	0.30	V	A2
2	31,400	1	180	3.3	0.30	V	A2
3	50,300	1	180	3.3	0.40	V	A1-2
4	52,800	1	400	3.3	0.25	V	A1-2
5	53596±115	2	170	3.3	0.25	H	A1-2
6	54,400	1	400	3.3	0.25	H	A1-1
7	54,940	1	400	3.3	0.25	V	A1-1
8	55,500	1	330	3.3	0.25	H	A1-2
9	f_0=57,290.344	1	330	3.3	0.25	H	A1-1
10	f_0±217	2	78	3.3	0.40	H	A1-1
11	f_0±322.2±48	4	36	3.3	0.40	H	A1-1
12	f_0±322.2±22	4	16	3.3	0.60	H	A1-1
13	f_0±322.2±10	4	8	3.3	0.80	H	A1-1
14	f_0±322.2±4.5	4	3	3.3	1.20	H	A1-1
15	89,000	1	<6,000	3.3	0.50	V	A1-1

[1] H indicates horizontal and V indicates vertical polarization.

3.3.2.2   Antenna/Drive/Calibration System

The Antenna/Drive/Calibration subsystem consists of a conical corrugated horn-fed shrouded reflector, multiplexer, closed-loop antenna scan drive assembly and closed path calibration assembly. The shrouded reflector is rotated once every scan line (8 sec) for:

   o   each of 30 earth viewing scene observations,

   o   a view of the cosmic background (~2.73 K), and

   o   a view of a warm calibration load (~300 K).

During the rotation cycle, the shroud prevents solar reflections from interacting with the warm load and also ensures maximum coupling of the source radiation to the antenna feed. A complete end-to-end in-flight calibration is achieved in a through-the-antenna method, which provides maximum in-flight calibration accuracy. The accuracy of the warm calibration load brightness temperature is better than ± 0.2 K. The closed loop antenna scan drive provides beam pointing accuracy within ± 0.2 degrees. A resolver in the antenna drive assembly provides antenna beam position information.

The AMSU-A1 modules contain two antenna assemblies: designated A1-1 and A1-2. Antenna A1-1 is located the farthest from Earth in-flight and provides inputs to channels 6 and 7 and channels 9 through 15.   A1-2 is located closest to Earth in-flight and provides input to channels 3 through 5 and 8.   Table 3.3.2.2-1 shows the number of PRTs contained in each of the AMSU-A modules. Figures 3.3.2.2-1 and 3.3.2.2-2 show actual photos from NASA for AMSU-A1 and AMSU-A2.

Table 3.3.2.2-1. The number of PRTs in each AMSU-A module.		
Instrument		**Number of PRTs**
AMSU-A1	A1-1	5*
	A1-2	5*
AMSU-A2		7*
* The number of PRTs specified for each calibration target in the AMSU-A instrument is four. Five were provided for AMSU-A1 and seven for AMSU-A2. The NOAA-K AMSU-A1-1 has one of the five PRTs inoperable.		

The antenna beamwidth of all AMSU-A channels is 3.3 degrees. The beamwidth is defined as the half-power points beamwidth (HPBW). The beamwidth in any plane containing the main beam axis (electrical boresight axis) is within $\pm 10\%$ of the 3.3 degree value. Beamwidth variation from channel to channel is smaller than 10% of the specified beamwidth value.

The polarization angle changes as a function of the scan angle. The polarization angle is defined as the magnitude of the angle between the electric field vector of the incoming radiation and a line which is the intersection of a plane perpendicular to the propagation direction of the incoming radiation and a plane tangent to the earth surface. Scan angle is defined as the angle between nadir and the antenna electrical boresight direction. Vertical polarization is defined as having the polarized vector in the sun-nadir plane when the beam is pointing at nadir. Horizontal polarization is defined as having the polarization vector in the velocity-nadir plane when the beam is pointing at nadir.

Each channel of the AMSU-A is considered to form a beam. All main beam axes of the AMSU-A are coincidental, i.e., they are pointing in the same direction at the same time for any given beam position. The AMSU-A beams have cross-track scanning. All beams scan in a plane perpendicular to the spacecraft orbital velocity vector. The sense of the scan is counter clockwise as one looks along the spacecraft orbital velocity direction, namely, the antenna scans from the sun direction through nadir to the cold space direction.

The scanning profile of AMSU-A is a "step" scan type. The instrument's FOV rotates to a data collection position, stops, collects data, and then moves to the next collection position, stops, collects data, etc. The instrument starts at each earth position 1, then goes sequentially to earth position 30, then to the cold calibration view position, and then to the warm load view position. After the warm load view, the instrument goes back to earth position 1 and the cycle begins again. See Appendix J.3 for specific scan parameters and patterns of the AMSU-A instrument.

The AMSU-A beams scan the earth viewing sector a total of 96.66 degrees (±48.33 degrees from nadir) on beam centers. There is a total of 30 beam positions (30 resolution cells on the earth's surface), which are called cell numbers 1 through 30, from sun to anti-sun. There are 15 cells on either side of nadir. The beam center position of each cell is separated from the adjacent cell along the scan direction by 3.33 degrees (there is a noncumulative step tolerance of ±0.04 degrees).

3.3.3   CALIBRATION REQUIREMENTS

There are no specific on-orbit calibration procedures for AMSU-A. The instrument is automatically calibrated each data cycle by measuring both warm and cold calibration targets.

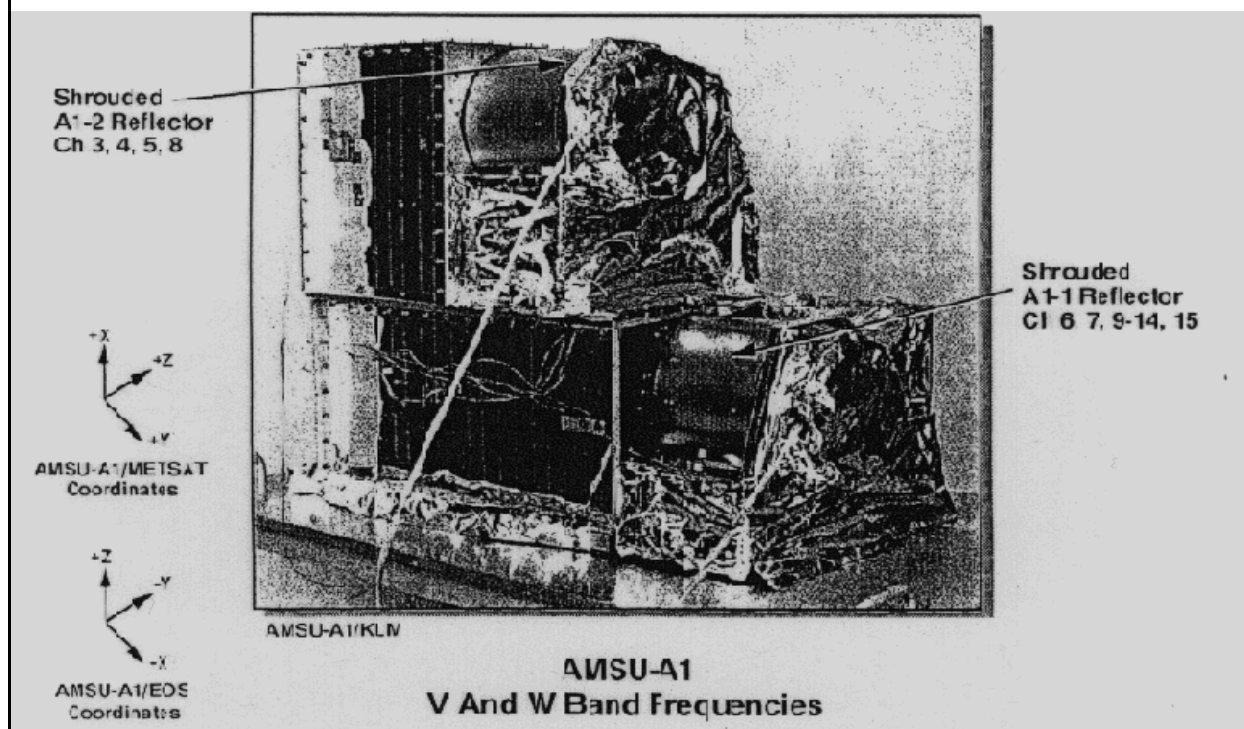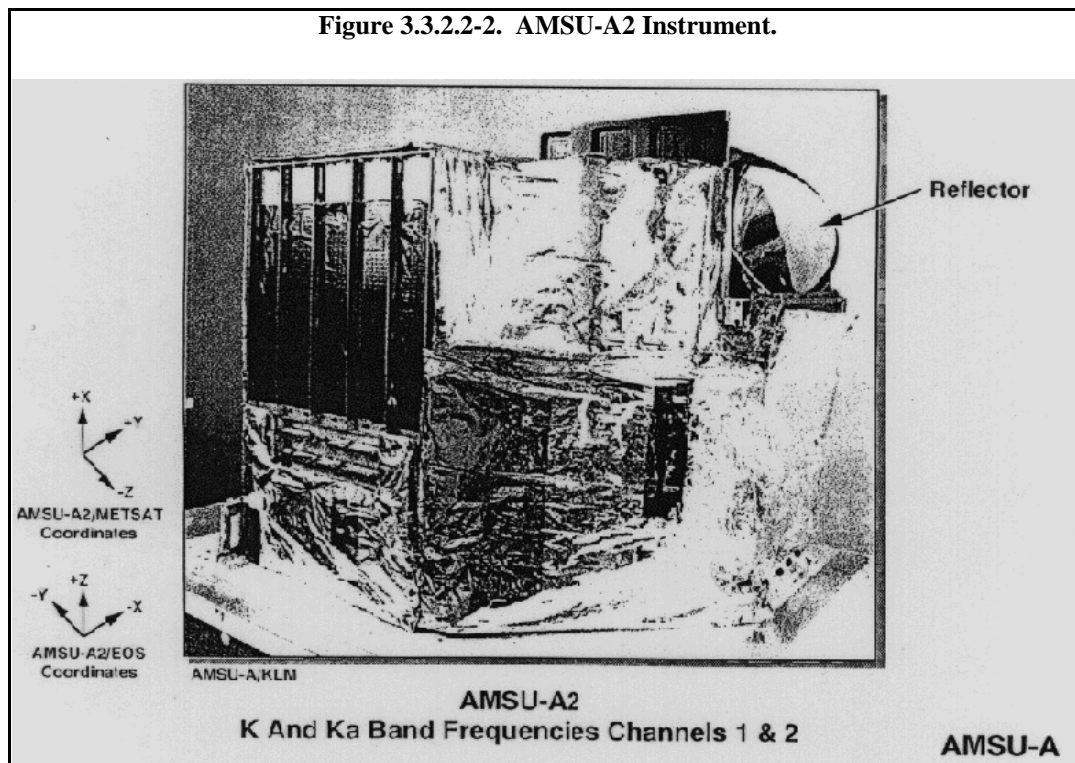**Figure 3.3.2.2-1. AMSU-A1 Instrument.**

Shrouded
A1-2 Reflector
Ch 3, 4, 5, 8

Shrouded
A1-1 Reflector
Cl 6 7, 9-14, 15

+X
+Z
+Y
AMSU-A1/METSAT
Coordinates

+Z
-Y
-X
AMSU-A1/EOS
Coordinates

AMSU-A1/KLM

AMSU-A1
V And W Band Frequencies

Figure 3.3.2.2-2. AMSU-A2 Instrument.

Reflector

+X
-Y
-Z
AMSU-A2/METSAT
Coordinates

+Z
-Y
-X
AMSU-A2/EOS
Coordinates

AMSU-A/KLM

AMSU-A2
K And Ka Band Frequencies Channels 1 & 2

AMSU-A

3.4   **ADVANCED MICROWAVE SOUNDING UNIT - B (AMSU-B)**

3.4.1   INSTRUMENT OPERATION

The Advanced Microwave Sounding Unit-B (AMSU-B) is a 5 channel microwave radiometer. The purpose of the instrument is to receive and measure radiation from a number of different layers of the atmosphere in order to obtain global data on humidity profiles. It works in conjunction with the AMSU-A instruments to provide a 20 channel microwave radiometer.

The microwave characteristics of the atmosphere are provided in Figure 3.4.1-1. AMSU-B covers channels 16 through 20. The highest channels: 18, 19 and 20, span the strongly opaque water vapor absorption line at 183 GHz and provide data on the atmosphere's humidity level. Channels 16 and 17, at 89 GHz and 150 GHz, respectively, enable deeper penetration through the atmosphere to the Earth's surface.

Figure 3.4.1-1. Microwave Characteristics of the Atmosphere.
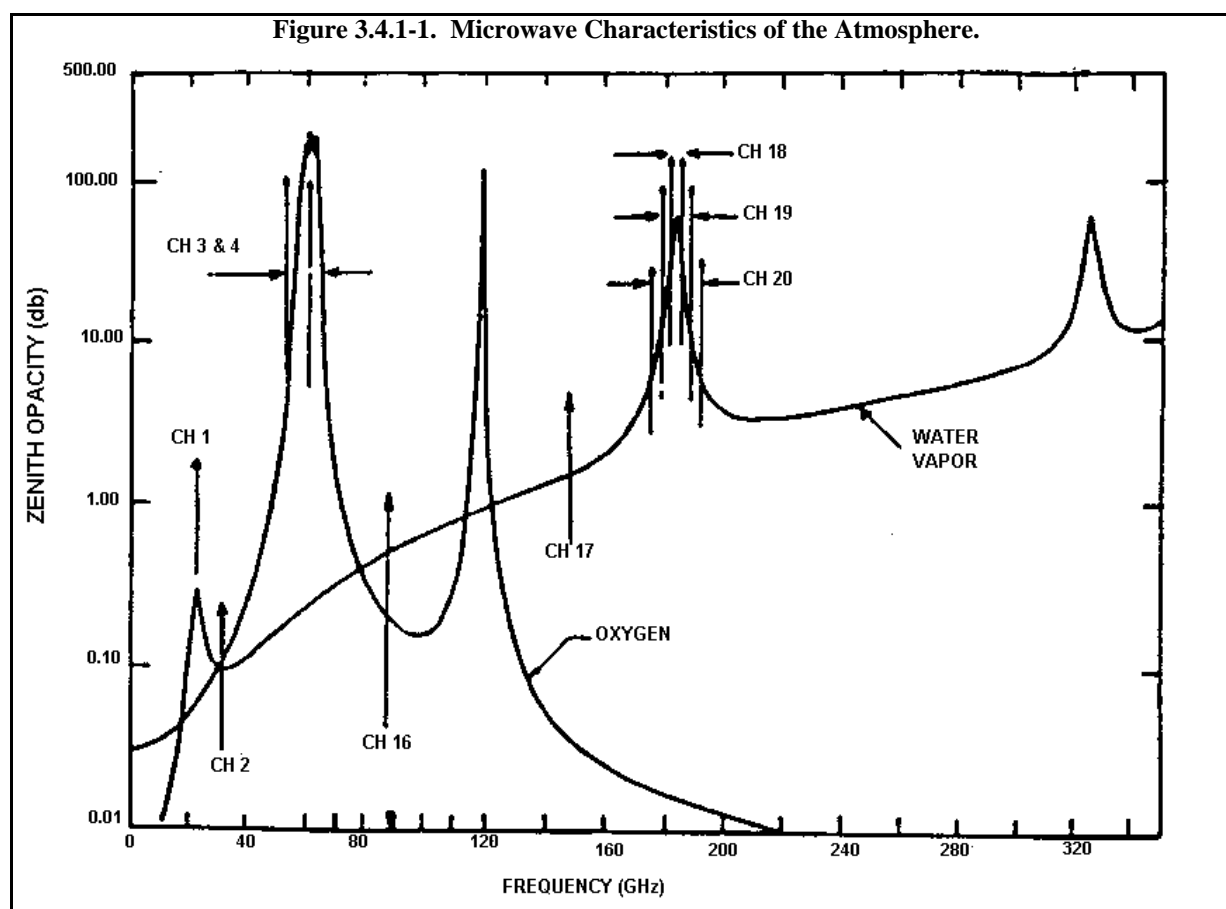
AMSU-B is a cross-track, line scanned instrument designed to measure scene radiances in 5

channels. At each channel frequency, the antenna beamwidth is a constant 1.1 degrees (at the half power point). Ninety contiguous scene resolution cells are sampled in a continuous fashion, each scan covering 50 degrees on each side of the subsatellite path. These scan patterns and geometric resolution translate to a 16.3 km diameter cell at nadir at a nominal altitude of 850 km. See Appendix J.3 for specific scan parameters and patterns for AMSU-B.

The AMSU-B instrument consists of a scanning parabolic reflector antenna which is rotated once every 8/3 seconds and focuses incoming radiation into a quasi-optic system which then separates the frequencies of interest into three separate feed horns of the receiver assembly. The receiver subsystem provides further demultiplexing of the 183 GHz signal in order to selectively acquire three defined double sided bands around the 183 GHz signal. The passbands for all five channels are shown in Table 3.4.1-1. The center frequencies for channels 18, 19, and 20 are 183.31 ± 1.00 GHz, 183.31 ± 3.00 GHz, and 183.31 ± 7.00 GHz, respectively. Further information regarding the AMSU-B channels can be found in Section 3.3.2.1

Table 3.4.1-1. AMSU-B Channel Characteristics (based on actual instrument build and measured NEΔT from thermal vacuum data).					
Channel number	Center freq. of channel (GHz)	No. of pass bands	Bandwidth per passband (MHz)	NEΔT[1] (K)	Polarization angle[2]
16	89.0±0.9	2	1000	0.37	90-θ
17	150.0±0.9	2	1000	0.84	90-θ
18	183.31±1.00	2	500	1.06	90-θ
19	183.31±3.00	2	1000	0.70	90-θ
20	183.31±7.00	2	2000	0.60	90-θ

[1] Values from first flight model.

[2] The polarization angle is defined as the angle from horizontal polarization (i.e., electric field vector parallel to satellite track) where θ is the scan angle from nadir. In this table, the polarization angle is horizontal when the angle indicated is θ and vertical when 90-θ.

The reflector is rotated in a profiled scan span, in order to provide a constant velocity Earth scan, a low speed scan across an internal calibration source, a low speed scan towards deep space and a scan repeat cycle time that does not allow for constant velocity rotation. The direction of the scan motion is from the sunside (+Z) to nadir (+X) to the antisunside (-Z). During earthscan, motion is continuous with an angular velocity constant to within ±2%. The deep space and internal blackbody reference views permit a two-point, in-flight calibration. The entire scan profile is achieved through microprocessor control.

Three different data streams are processed and delivered by the instrument to either the

spacecraft's AMSU Instrument Processor (AIP) or the TIROS Information Processor (TIP). Digital data, which consist of earth view pixel data, housekeeping data, and space and blackbody view data, is clocked into the AIP. The TIP samples both digital "B" and analog telemetry. The digital "B" telemetry contains instrument status monitors used to verify commands, and the analog telemetry provides health and safety monitoring of AMSU-B.

3.4.2   SYSTEM DESCRIPTION

3.4.2.1   <u>General</u>

The overall purpose of AMSU-B is to receive and measure radiation from a number of different layers within the atmosphere in order to obtain global data on humidity profiles.

The radiation from the atmosphere is viewed by an offset parabolic reflector inclined to the axis of rotation. The antenna is rotated by means of a scanning mechanism which is capable of slewing the antenna between hot and cold calibration references and scanning the antenna to view a swath across the atmosphere. Radiation from the antenna is propagated via a fixed sub-reflector to a quasi-optic feed where it is divided into 89, 150 and 183.3 GHz bands and then to a Microwave Receiver where it is down-converted, amplified and detected. The detected signals are amplified, sampled and averaged under processor control to provide an integration time of 18 msec in each

channel. The digital signals are then buffered before being relayed to the satellite bus.

The AMSU-B consists of the following:

       o   Microwave and Antenna Subsystem (MASS) comprising:

               -      Main Reflector/Shroud

               -      Subreflector

               -      Quasi-Optic Feed

               -      Microwave Receiver

               -      Calibration Target

       o   Scanning Mechanism

o   Electrical Subsystem comprising:

-        Processing Electronics Unit (PEU)

-        Motor Drive Electronics (MDE) and Inductosyn Control Electronics (ICE)

-        Power Supply Unit (PSU)

-        Electrical Harness

o   Structure Subsystem

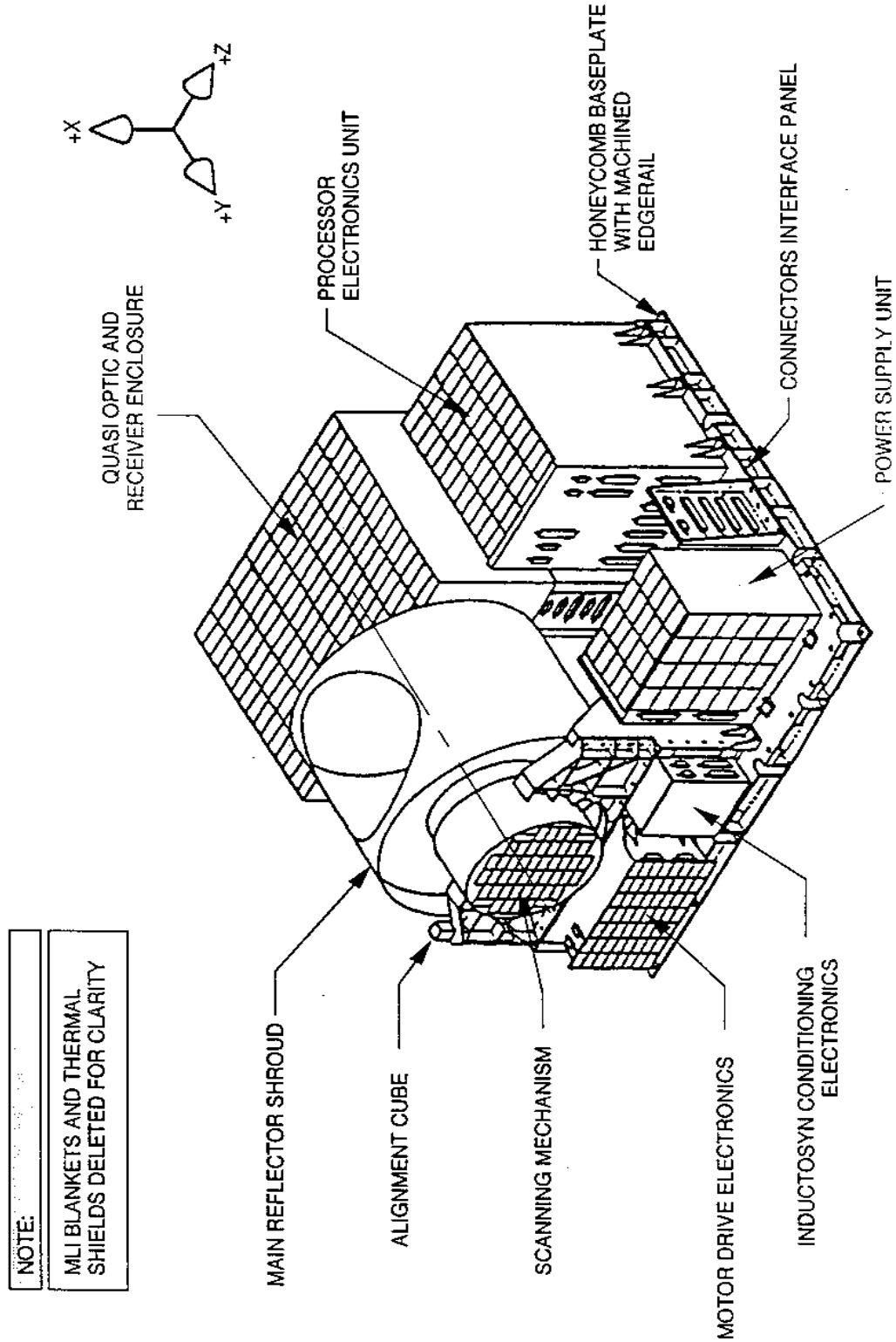o   Thermal Control Subsystem

o   Software

A general configuration view of AMSU-B is shown in Figure 3.4.2.1-1.

3.4.2.2   <u>Microwave Receiver</u>

The function of the Receiver Subsystem is to down-convert and detect the radiation from the Quasi-Optics to produce output voltages proportional to the detected RF power. The Receiver has three input channels and five output channels. Channel 16 uses a fundamental mixer with a center frequency of 89 GHz. Channel 17 uses a sub-harmonic mixer with a center frequency of 150 GHz. Channels 18, 19 and 20 are down-converted in one sub-harmonic mixer with a center frequency of 183.3 GHz. The IF output of the mixer is split and detected to produce the three channel outputs. The AMSU-B channel characteristics are shown in Figure 3.4.1-1. The receiver utilizes Gunn diode oscillators which are cavity stabilized and are of the reflection type. The diodes are Germanium mesa construction especially developed for AMSU frequencies.

The temperatures of certain critical components of the Receiver Sub-system are sensed by AD590 temperature/current transducers for Analog Telemetry or by Platinum Resistance Thermistors (PRTs) for Digital Housekeeping Data.

Figure 3.4.2.1-1. AMSU-B General Configuration.

NOTE:

MLI BLANKETS AND THERMAL
SHIELDS DELETED FOR CLARITY

+Z

+X

+Y

PROCESSOR
ELECTRONICS UNIT

QUASI OPTIC AND
RECEIVER ENCLOSURE

HONEYCOMB BASEPLATE
WITH MACHINED
EDGERAIL

CONNECTORS INTERFACE PANEL

POWER SUPPLY UNIT

MAIN REFLECTOR SHROUD

ALIGNMENT CUBE

SCANNING MECHANISM

MOTOR DRIVE ELECTRONICS

INDUCTOSYN CONDITIONING
ELECTRONICS

3.4.2.3   Calibration Target

The radiometer is continually calibrated in flight with the aid of a cold reference view to space and a "warm" reference consisting of an ambient temperature Calibration Target. The "warm" reference is internal to the instrument. It consists of the following:

- microwave absorber providing quasi-blackbody radiation at microwave frequencies,

- a magnesium structured core,

- platinum resistance sensors to measure the temperature of the magnesium core accurately,

- an outer containment shroud of aluminum.

The Calibration Target presents a stable, high absorptivity, or quasi-blackbody load at approximately 290K (at nominal instrument temperature) into the instrument Main Reflector and is sized to fill the aperture in the Main Reflector/Shroud. The Calibration Target is viewed once during each scan of the instrument to provide a warm calibration reference. Gain is then computed from FOV counts taken at each of the two views and used to determine a radiance value for each channel. Apparent scene temperatures are finally calculated from the radiance values.

An integral shroud is fitted to match the main reflector/shroud, so that, as the Main Reflector is rotated, extraneous radiation impinging on the target is minimized.

Temperature control of the Calibration Target is passive and is designed to minimize temperature gradients within the target. Target temperature is sensed by seven Platinum Resistance Thermistors (PRTs) whose outputs are conditioned and digitized by the PEU and form part of the digital data telemetry.

3.4.2.4   Systems Requirements

A summary of the AMSU-B systems requirements is given in Table 3.4.2.4-1.

Table 3.4.2.4-1. AMSU-B Systems Requirements Summary.					
Channel	**16**	**17**	**18**	**19**	**20**
Frequency (GHz)	89	150	183.3±1	183.3±3	183.3±7
RF Bandwidth (GHz)	2 x 1	2 x 1	2 x 0.5	2 x 1	2 x 2
ΔT Temperature Sensitivity	1.0 K	1.0 K	1.1 K	1.0 K	1.2 K
Calibration Accuracy	1.0 K (± 0.2 K Random)	1.0 K (± 0.2 K Random)	1.0 K (± 0.2 K Random)	1.0 K (± 0.2 K Random)	1.0 K (± 0.2 K Random)
Linearity	0.3 K	0.3 K	<0.33 K	0.3 K	0.36 K
Interchannel Calibration Accuracy	0.5 K	0.5 K	0.5 K	0.5 K	0.5 K
Beam Efficiency	>95%	>95%	>95%	>95%	>95%
Beamwidth	1.1 degrees ±10%	1.1 degrees ±10%	1.1 degrees ±10%	1.1 degrees ±10%	1.1 degrees ±10%
Beam Pointing Accuracy	±0.10 degrees	±0.10 degrees	±0.10 degrees	±0.10 degrees	±0.10 degrees
Cross Polarization	2%	2%	N/S	N/S	10%
Passband Sensitivity	<1.5 dB over 75% of passband				
Mass	60 kg				
Power	90 W				
Accommodation	526 mm x 700 mm x 650 mm				
Life & Storage	3 years & 4 years				
Scan Motion	See Appendix J.3 for more information.				
Scan Profile	See Appendix J.3 for more information				
Scan Angle	±48.95 degrees				
Scan Period	8/3 seconds				
Calibration Views	≤4 degrees				
Scan Modes	Normal, Park, Step, Investigation				

3.5   SPACE ENVIRONMENT MONITOR (SEM-2)

3.5.1   INSTRUMENT OPERATION

The SEM-2 Space Environment Monitor is a multichannel charged-particle spectrometer which senses the flux of charged particles at the satellite altitude, and thus contributes to knowledge of the solar-terrestrial environment. SEM-1 units have been in orbit on the TIROS-N series since 1978. SEM-2 is a new design produced by Panametrics, Inc. of Waltham, Massachusetts to specifications written by the Space Environment Center of NOAA.

Solar particle emissions travel to Earth in the form of the solar wind, which consists of streams of charged particles moving at hundreds of kilometers per second. It is a source of particles for the Earth's trapped radiation belts. In addition to the solar wind, there occur times of intense fluxes of energetic electrons, protons and alpha particles (energies up to 1,000 MeV). As a consequence of both the solar wind particle stream and the occurrences of very energetic particle emissions from the Sun, there can be large changes to the energy input to the magnetosphere, ionosphere and high altitude atmosphere. Some of this energy is deposited into the ionosphere to produce the aurora visible around both magnetic poles.

Large, abrupt changes occur in the solar wind. These changes produce changes in the magnetosphere and the ionosphere. This can result in hazards among which are:

1.   Radiation hazard to people in space and the potential of increased radiation exposure to people in high flying aircraft;

2.   Disruption of radio navigation;

3.   Absorption, even blackout, of radio waves so that radio communication is disrupted;

4.   Induced voltages and currents in electric power circuits leading to circuit breaker trip, damage to equipment, and failure of transformers;

5.   Induced currents in buried pipe lines causing accelerated corrosion;

6.   Change in density of the high altitude atmosphere causing change in drag on satellites;

7.   Change in magnetic torque on satellites; and

8.   Damage by electrons and protons to satellite circuits and solar panels.

For these reasons, SEM-2 is specified to sense particles over a broad range of energies. SEM-2 consists of two detectors: the total energy detector (TED) and the medium energy proton and electron detector (MEPED) along with a data processing unit (DPU).

3.5.1.1   Total Energy Detector

The Total Energy Detector (TED) measures electron and proton energy fluxes in the 0.05 to 20 keV energy range.

Two independent measurements of the particle energy flux are made at zero and 30 degrees from the local vertical. The total energy measurement is divided into two ranges: 0.05 to 1 keV and 1 to 20 keV and each measurement is made independently for electrons and protons. The TED also measures the maximum differential energy flux density and the energy at which it occurs for each direction and particle type (electron and proton).

TED operation is verified by a commandable In-Flight Calibration system to track changes in the TED electronics.

3.5.1.2   Medium Energy Proton Electron Detector

The Medium Energy Proton Electron Detector (MEPED) provides both directional and omni-directional measurements. The directional sensors, called telescopes, make independent measurements of the particle types in the energy intervals shown in Table 3.5.1.2-1. Directional measurements are made near the local vertical and near 90 degrees to the local vertical. The particle channels are designated by direction of view (0 or 9), particle type (E or P), and sequential energy range (1-6 for protons, 1-3 for electrons). Table 3.5.1.2-1 contains the particle types and energy intervals measured by the MEPED directional sensors.

Table 3.5.1.2-1. Particle types and energy intervals measured by the MEPED directional sensors.		
Particle type	**Channel Designations**	**Energy Interval (keV)**
Protons	0P1 and 9P1	30-80
	0P2 and 9P2	80-250
	0P3 and 9P3	250-800
	0P4 and 9P4	800-2500
	0P5 and 9P5	2500-6900
	0P6 and 9P6	>6900 integral
Electrons	0E1 and 9E1	>30 integral
	0E2 and 9E2	>100 integral
	0E3 and 9E3	>300 integral

The omni-directional sensors measure proton energy in the following ranges: >16 MeV, >35 MeV, >70 MeV and >140 MeV. Each sensor consists of a dome of moderating material which absorbs energy from the particle (and so sets the detection energy threshold), a silicon solid state detector (SSD), a preamplifier, and a level comparator which responds to particles with enough energy to go through the moderator and produce a pulse from the detector large enough to exceed the level in the comparator.

The MEPED has an In-Flight Calibration (IFC) circuit started by command from the ground. Using pulses of increasing size, the calibration provides data for calculating the energy of each threshold and the noise (FWHM) of each directional channel.

3.5.1.3   Data Processing Unit

The Data Processing Unit (DPU) is the interface between the sensors and the spacecraft. It converts spacecraft power to the voltages required by the SEM-2. It counts pulses, scales them, combines some, and formats a data stream for Digital A telemetry. It digitizes analog monitors of TED, MEPED, and DPU circuits. Independent of whether SEM-2 power is on or off, some temperatures are monitored by the spacecraft.

The DPU provides bi-level monitors, via Digital B telemetry, of SEM-2 status. The DPU receives and processes commands from the ground through the spacecraft to operate SEM-2.

3.5.2 SYSTEM DESCRIPTION

3.5.2.1 Total Energy Detector

The Total Energy Detector (TED) consists of eight Electrostatic Analyzers (ESA), pulse height discriminators (PHD), an In-Flight Calibrator (IFC), two high voltage (HV) supplies, a sweep voltage supply and housekeeping circuits.

The ESA selects particles according to their charge and energy using curved plates which apply an electric field to the particles as they pass through the ESA. Only particles of the selected charge and energy can pass entirely through the ESA. At the outlet of the ESA is a continuous dynode electron multiplier (CDEM). The CDEM produces a pulse for each particle passed by the ESA.

The voltage applied to the ESA curved plates steps up through a series of exponential values to allow particles of increasing energy to pass through. Timing by the DPU determines the energy counter in which the CDEM pulses are accumulated.

There are commandable HV supplies for the electron CDEMs (up to 3,700 V) and for the proton CDEMs (up to 2,700 V) that compensate for gain degradation of the CDEMs with use.

3.5.2.2 Medium Energy Proton Electron Detector (MEPED)

The MEPED consists of two proton telescopes, (each containing two solid state detectors (SSDs)), two electron telescopes (each containing a single solid state detector) and four Omni-directional sensors (each containing a single solid state detector), Charge Sensitive Preamplifiers, Analog Signal Processors, Proton and Electron Coincidence Logic, In-Flight Calibrator, Low Voltage Regulators, SSD Bias Supply and Analog Housekeeping.

The two proton telescope sensors are located at 0 and near 90 degrees to the local vertical. Each sensor has logic circuits which select six energy ranges from 30 keV to greater than 6900 keV. The energy intervals detected are shown in Table 3.5.2.2-1.

Table 3.5.2.2-1. Proton telescope detection energy intervals.	
Energy Interval Designation	**Ep Range (keV)**
0P1 and 9P1	30-80

0P2 and 9P2	80-250
0P3 and 9P3	250-800
0P4 and 9P4	800-2500
0P5 and 9P5	2500-6900
0P6 and 9P6	>6900

The two electron telescopes sensors are located at 0 and near 90 degrees to the local vertical. Each sensor has logic circuits which select three energy thresholds from 30 keV to 300 keV. Each energy channel has a veto for particle energy deposits of >2500 keV, which reduces the contamination from high energy proton fluxes. The energy intervals are shown in Table 3.5.2.2-2.

Table 3.5.2.2-2. Electron telescope detection energy intervals.	
Energy Interval Designation	**Ee Range (keV)**
0E1 and 9E1	>30
0E2 and 9E2	>100
0E3 and 9E3	>300

The four Omni-directional Proton Sensors, D4, D5, D6 and D7 have energy thresholds at 16, 35, 70 and 140 MeV, respectively.

A charged particle enters a SSD where it releases charges from the crystal until its energy is gone or it exits the crystal. The amount of charge released is proportional to the energy deposited in the crystal. The charge is collected by a charge sensitive preamplifier which converts the charge to a voltage pulse. After passing through an analog signal processor circuit, which shapes the pulse by pole-zero cancellation, single differentiation, double integration and baseline restoration, coincidence logic separates the pulses into the various channels for counting by the DPU.

Regulated voltage for the SSDs is provided by an SSD bias supply. An in-flight calibrator (IFC) puts pulses into the charge sensitive preamplifier inputs to check the complete analog signal processor and coincidence logic circuitry. The IFC data are telemetered the same as the normal particle data. Thresholds and noise values are calculated on the ground.

3.5.2.3   Data Processing Unit

The Data Processing Unit (DPU) is the sole electrical interface between the detectors and the spacecraft except for the TED and MEPED heaters. It converts spacecraft power to the voltages required by the SEM. It counts pulses, scales the counts, combines some, and formats a data stream for Digital A. It digitizes analog monitors of TED, MEPED and DPU voltages and temperatures. Independent of whether SEM-2 power is on or off, some temperatures are monitored by the spacecraft. The DPU provides bi-level monitors via Digital B of SEM-2 status. The DPU receives and processes commands from the ground through the spacecraft to control SEM-2.

The DPU interfaces with, and controls, the TED and MEPED. The DPU performs the following tasks:

- Converts +28 V Main Bus power to SEM-2 voltages;

- Receives commands from the spacecraft and controls the TED and MEPED accordingly;

- Counts high speed pulse data from the MEPED and TED;

- Provides Digital A, Digital B bi-level and spacecraft analog output to the spacecraft telemetry;

- Controls the In-Flight Calibration.

The DPU contains four "active" Printed Circuit Boards (daughter boards) and one "passive" PCB (mother board). The DC/DC converter is contained in a Faraday cage to reduce radio frequency interference (RFI) which might be caused by "high power" switching. SEM-2 operation is controlled by two redundant microprocessors, one of which is selected by ground command to be active.

3.5.2.3.1   Telemetry

Within the DPU three types of telemetry are generated: Digital A, Digital B and Analog.

3.5.2.3.2   Digital A

Digital A contains most of the telemetered data and consists of two 8-bit serial words made available to the spacecraft every 0.1 second, i.e., every minor frame.

3.5.2.3.3   Digital B

Digital B (DIGB) consists of 9 bits always available to the spacecraft. DIGB is updated by the DPU each 2.0 seconds. The spacecraft samples these each 3.2 seconds.

3.5.2.3.4   Spacecraft Analog Telemetry

A third type of data, analog telemetry, goes to the spacecraft. In this type, thirteen analog monitors are provided. Nine of these monitors verify command execution and indicate general state of health. These nine are also digitized and included in Digital A. The remaining four are temperature monitors powered by the +28 V Analog Telemetry Bus, which allows the DPU, MEPED and TED housing temperatures, as well as one MEPED proton telescope temperature, to be monitored regardless of whether the instrument is on or off. These temperature monitors are not digitized by the DPU, but are processed directly by the TIP.

3.5.2.3.5   Timing

All timing is controlled by the microprocessor and is synchronous with the spacecraft 1.248 MHZ clock. Various data acquisition timing signals are spawned from a single timing chain to ensure proper signal phase. DPU timing has the following parts:

- Data acquisition Timing for TED and the MEPED

- Digital A Timing

- Microprocessor and Data Bus Timing

- Watchdog Timing

3.5.3   CALIBRATION REQUIREMENTS

The SEM-2 provides an In-Flight Calibration (IFC) for the MEPED and the TED.

3.6   DATA COLLECTION SYSTEM/2 (DCS/2)

3.6.1   INSTRUMENT OPERATION

The Data Collection System/2 (DCS/2) is one of the environmental monitoring systems to be flown on the NOAA KLM spacecraft. The DCS/2 will assist NOAA in its overall environmental mission and in support of the Global Atmospheric Research Program (GARP). It is planned to have 2000 environmental platforms located around the Earth to measure such environmental factors as temperature, pressure, and currents. Some of these platforms will be immersed in a moving fluid, such as the ocean and the atmosphere. These moving platforms, buoys and balloons, will provide additional environmental information on velocity and direction of the ocean and wind currents.

The DCS/2 will receive information from these fixed and moving environmental platforms and will process and transfer the data for storage by the spacecraft tape recorders. These stored data will be transmitted to a NOAA KLM ground station during station contact. The ground station will record and transmit the DCS/2 data to the French Centre National D'Etudes Spatiales (CNES) and to Service ARGOS in Landover, Maryland. CNES is the responsible manufacturing, system engineering and data distribution agency for the DCS/2.

3.6.2   SYSTEM DESCRIPTION

The DCS/2 is comprised of three units: the Receiving and Power Unit (RPU) and two Signal Processor Units (SPU-A and SPU-B). The platforms transmit data to the DCS/2 at a carrier frequency of 401.650 MHz, digital biphase format at 400 bps. The DCS/2 demodulates this signal and determines the carrier frequency and relative time of each transmission. This data is processed, formatted, and transferred to the TIROS Information Processor (TIP). The following paragraphs describe how the processing occurs in each of the DCS/2 units.

3.6.2.1   Receiver Power Unit

The receiver linearly converts the incoming signal by means of two translations to an intermediate frequency which is applied to the input of the search unit and to the Data Recovery Units (DRUs). The search unit is basically a spectrum analyzer which uses a Fast Fourier Transform to cover the 80 kHz operating frequency range.

3.6.2.2   Control Unit

The control unit sequentially scans the eight search unit channels. It makes a binary estimate of both the signal level and frequency. These two digital words are stored in the CU and are used for the assignment of a DRU to a particular receiver output signal.

3.6.2.3   Data Recovery Unit

The DRU is comprised of three sections: (1) phase-lock loop, (2) bit synchronizer, and (3) Doppler counter and formatter. The eight DRUs perform the following signal functions: acquisition of the carrier, signal demodulation, bit synchronization, frame synchronization, Doppler counting, decommutation and formatting of the data.

3.6.2.4   Telemetry Encoder and Memory

The telemetry formatter interrogates the buffer in the DRUs. When the buffer is full, the encoder sends a command to shift the 24 bits into memory. When the data transfer signal from the TIP is received by the encoder, it will transfer the data out of memory to the TIP.

3.6.2.5   Power and Command Unit

Power for the DCS/2 is supplied by the spacecraft +28 V main power bus. This voltage is converted by the power unit to four levels; +5.0, +12, -12, and -15 V. Regulation and current limitation is provided for each of these DCS buses. The command unit consists of seven relays which perform the ON/OFF functions for the DCS/2. The Control Interface Unit (CIU) sends pulse commands which control these relays. The command unit sends back to the TIP 14 status bits and six analogs.

3.6.3   CALIBRATION REQUIREMENTS

The DCS/2 has no on-orbit calibration requirements.

**3.7   SEARCH AND RESCUE SATELLITE (SARSAT) INSTRUMENT
          PACKAGE**

General aviation aircraft are required to carry Emergency Locator Transmitters (ELTs), which
are triggered by the impact of a crash and broadcast a signal at 121.5 and 243 MHz. These
transmissions can be heard as siren like sounds on receivers of aircraft which may be flying over
the transmitter. In addition, certain large ships are also required to carry 121.5 MHz Emergency
Position Indicating Radio Beacons (EPIRBs) which also transmit the siren like sound. Some
ocean going vessels voluntarily carry the EPIRBs.

It has been recognized for many years that receipt of ground transmissions by overflying
satellites includes a Doppler shift of the transmitted frequency due to the velocity of the satellite
relative to the transmitter. This Doppler shift information can be used to locate the transmitter.
The Search and Rescue (SAR) Instrument Package first flown on NOAA-E and subsequent
NOAA satellites carries a repeater for receiving and rebroadcasting the 121.5 and 243 MHz
signals to a ground station where they can be detected and located by measuring their Doppler
shift. However, these ELTs and EPIRBs were conceived prior to the satellite system and lack
specifications which assure reliable detection through the satellite. Even so, by the launch of
NOAA-H, over 1,000 people had been saved by SAR forces making use of satellite-derived
alerts and locations.

A 406 MHz SAR system has been designed specifically to work with the satellites. The NOAA
satellite SAR Instrument Package carries a 406 MHz processor which receives transmissions
from 406 MHz ELTs and EPIRBs, recovers their digital message, measures the Doppler shift,
and both stores the data for later transmission and also transmits it in real time. A receiver for
the 406 MHz band is also included in the repeater. This new system utilizes distress
transmitters (ELTs and EPIRBs) designed to be compatible with the satellite and the system
provides full global coverage. The 406 MHz system was demonstrated, evaluated and declared
ready for operational use by the time of the NOAA-H launch. Beginning with NOAA-H, the
406 MHz processor began utilizing a solid state memory for storage of the global data. Prior to
NOAA-H, the processors used the spacecraft tape recorder for global storage.

The NOAA KLM satellites carry an improved 406 MHz processor, designated SARP-2. This
unit has improved performance in system capacity, bandwidth, and protection against
interference.

3.7.1   INSTRUMENT OPERATION

The SARSAT Instrument Package for the NOAA-K spacecraft consists of antennas/ diplexer/
filters, a search and rescue repeater (SARR) and a search and rescue processor (SARP-2) as
shown in Figure 3.7-1.

o   SARSAT Antennas

SRA receive antennas

121.5/243 MHz

406 MHz

UDA receive antenna

401.65/406.050 MHz

SLA transmitter antenna

1544.5 MHz

o   SARR

o   SARP-2

The SARR operates as a "bent-pipe" repeater for the 121.5 MHz, 243 MHz, and 406.05 MHz bands and relays these transmissions from the ground-based emergency transmitters to Local User Terminals (LUTs) in real time. The SARR also transmits the SARP-2 digital data stream. The 406.05 MHz band of the SARR is for test and interference monitoring purposes, the normal processing is performed by the SARP-2.

After frequency translation, the base band spectra of the three signals phase modulate a 1544.5-MHz L-band transmitter for data relay to the ground. This technique maintains the Doppler information contained in the received signal from the three repeated bands. By processing the Doppler information at the LUT, the location of the emergency transmitter can be determined.

SARP-2 406.05-MHz signal data are both relayed in real time to the LUTs (if in sight) and stored for later transmission over a LUT when it comes in view of the satellite. SARP-2 signals are received on the Ultra High Frequency (UHF) Data Collection System Antenna (UDA), which the SARP-2 shares with the DCS-2. A frequency diplexer is used to separate the SARP-2 signals from DCS-2 signals. The SARP-2 measures the frequency and level of the incoming signal. In its data stream are a time tag, frequency and level information, a synchronization code indicating the start of each received message and the original message contained in the incoming signal. The data are stored in the SARP-2 last-in-and first-out circular memory, which continuously transmits its contents via the SARR L-band link at 2.4 kbps. When the memory is

Figure 3.7-1. SARSAT Instrument Package.
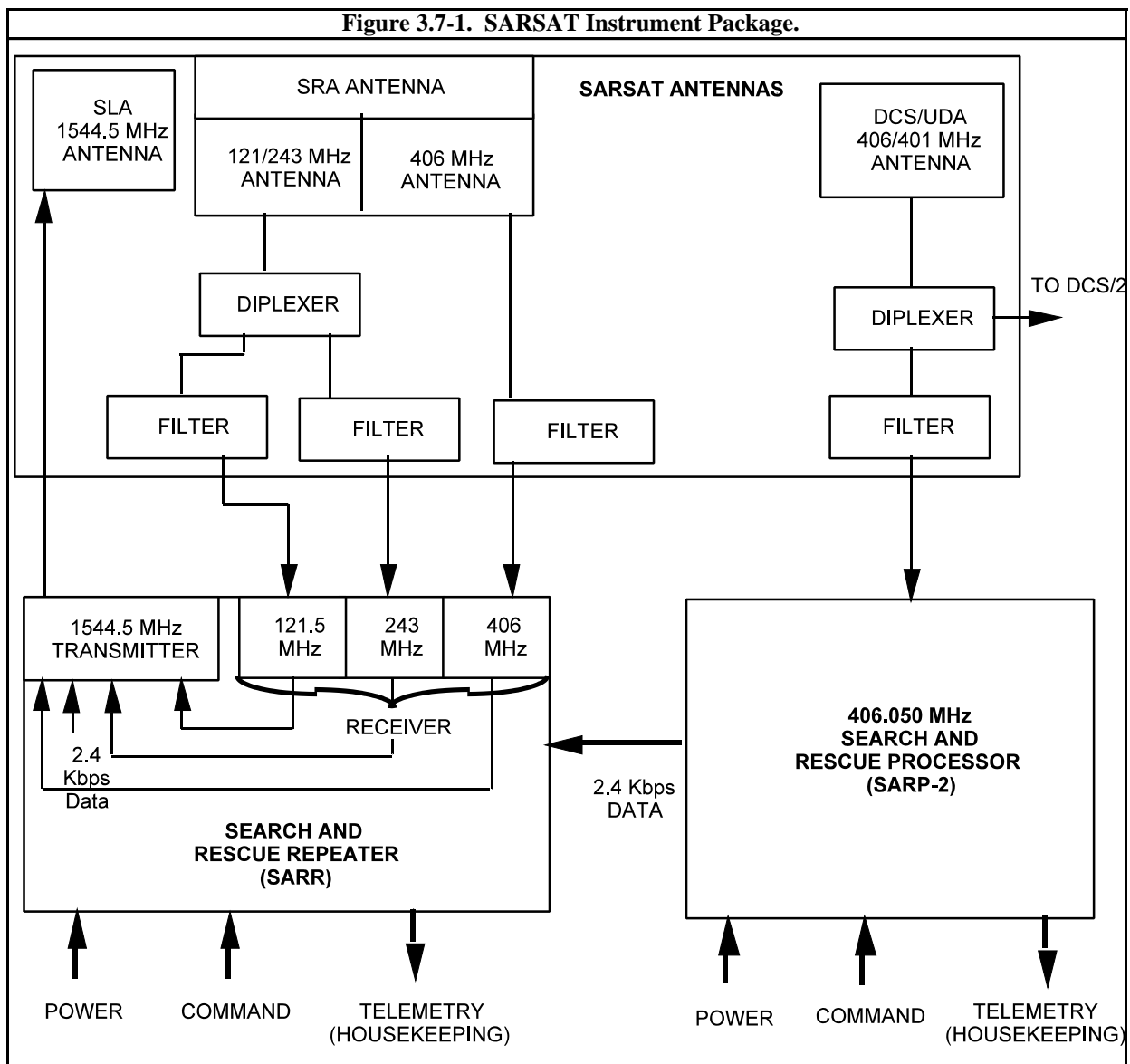
full, new data overwrites the oldest message. The memory readout pauses at the conclusion of a message block to allow transmission of new data and then continues its cyclic transmission with the new message, having erased and replaced the oldest message.

The SARP-2 and SARR data are received by the CDA stations via either the HRPT downlink or the TIP beacons.

The SARP-2, which is flown on NOAA KLM, provides the stored data interleaved with the real-time data in the 2.4 kbps data stream sent through the 1544.5 MHz downlink transmitter.

The output of the SARSAT Instrument Package is four frequency multiplexed signals on the 1544.5 MHz downlink transmitter.

        (a)   2.4 kbps data

        (b)   121.5 MHz band translated

        (c)   243 MHz band translated

        (d)   406 MHz band translated

The SARR instrument will output SARP-2 data and data stored in the SARP memory. The SARP-2 2.4 kbps data output consists of a Doppler frequency measurement (appropriately time-tagged) which includes the SAR data message from the ELT/EPIRB.

For the regional coverage mode, 2.4 kbps real-time data are transmitted to a Local User Terminal (LUT) via the SAR Repeater downlink. Global area coverage is provided by storing global 2.4 kbps data in a 406 Processor memory; these data are also transmitted to a LUT via the SAR Repeater downlink, but only during times when there is no regional coverage 2.4 kbps data to be transmitted.

3.7.2   SYSTEM DESCRIPTION

The orbiting SARSAT Instrument Package receives signals from ground-based ELTs/EPIRBs and returns them to both raw form and preprocessed form (406 MHz Experimental Units only) to one or more ground stations. Table 3.7-1 shows the SARSAT Subsystem Characteristics, while Figure 3.7-1 shows the SARSAT Instrument Package which consist of three elements:

        (a)   SARSAT Antennas;

        (b)   SAR Repeater (SARR) and

        (c)   SAR Processor (SARP-2).

3.7.2.1   SARSAT Antennas

The antenna subsystem consists of the:

        (a)   SAR Receiver Antenna (SRA);

(b)   Data Collection System Ultra High Frequency (UHF) Antenna referred to as DCS/UDA and

(c)   SAR L-Band Transmitter Antenna (SLA).

3.7.2.1.1   <u>SARSAT Receiver Antennas</u> - The SRA feeding the SARR consists of two coaxial Quadrifiliar designs. The outer quadrifiliar operates at two frequencies: 121.5 MHz and 243.0 MHz. The inner quadrifiliar operates at 406.05 MHz. The DCS/UDA is a quadrifiliar design and operates at 406.050 MHz for SARP-2 and also 401.650 MHz for the Data Collection System/2 (which is not part of the SARSAT instrument package).

The Search and Rescue Receiver antennas are mounted on a boom which is deployed clear of the other spacecraft instruments, antennas and solar array. There are four receive antenna ports for the SARSAT instruments: three for the SARR, and one for the SARP-2.

The 243 MHz and 406 MHz for both SRA and UDA receiving antenna patterns are shaped partially to compensate for increased signal path losses for ELTs at increasing distances from the subsatellite point.

3.7.2.1.2   <u>L-Band Transmitter Antenna</u> - The L-Band transmitter antenna is a small 1544.5 MHz quadrifiliar helix located on the Earth-facing side of the spacecraft which has a single lobe pattern for full Earth coverage. There is one transmit antenna port for connection to the SLA of the SARR.

3.7.2.2   <u>SAR Repeater (SARR)</u>

As shown in Figure 3.7-1, the SARR subsystem receives the ELT/EPIRB signals on 121.5, 243.0, and 406.05 MHz, down converts to selected intermediate frequencies, remodulates this data, and retransmits on 1544.5 MHz (repeater data mode). The baseline concept is that each receiver is a dual conversion unit with automatic gain control (AGC) which converts the received bandwidth down to a frequency range between 35 kHz and 210 kHz. These bands are then summed with 2.4 k-bit data from the SAR 406 MHz processor and phase modulated on the 1544.5 MHz downlink carrier frequency. The modulation level of each band is independently adjustable to account for any long-term changes either in the operational procedure or the system noise environment.

Each channel includes a commandable attenuator that allows the modulation index to be varied independently, subject to the constraint that the composite rms modulation index shall not exceed 0.74 radians.

The 2.4 kHz channel is controllable in 5 dB steps, whereas the 121.5, 243 and 406 MHz channels are controllable in 1 dB steps.

3.7.2.3   SAR Processor (SARP-2)

The 406.050 MHz on-board processor (see Figure 3.7.2.3-1) receives the 406 MHz transmissions from distress beacons and translates to an Intermediate Frequency (IF) using a double conversion. The IF signal is demodulated in a phase-lock loop to recover the data; the carrier frequency is measured and the data time tagged. For the regional coverage mode, real-time data are transmitted to a LUT via the SARR downlink. Global area coverage is provided by storing global data in a 406 Processor memory; these data are also transmitted to a LUT via the SARR downlink, but only during times when there is no regional coverage data to be transmitted.

The received signal is fed first to the receiver power unit (RPU) which utilizes a double

Figure 3.7.2.3-1. SARP-2 Block Diagram
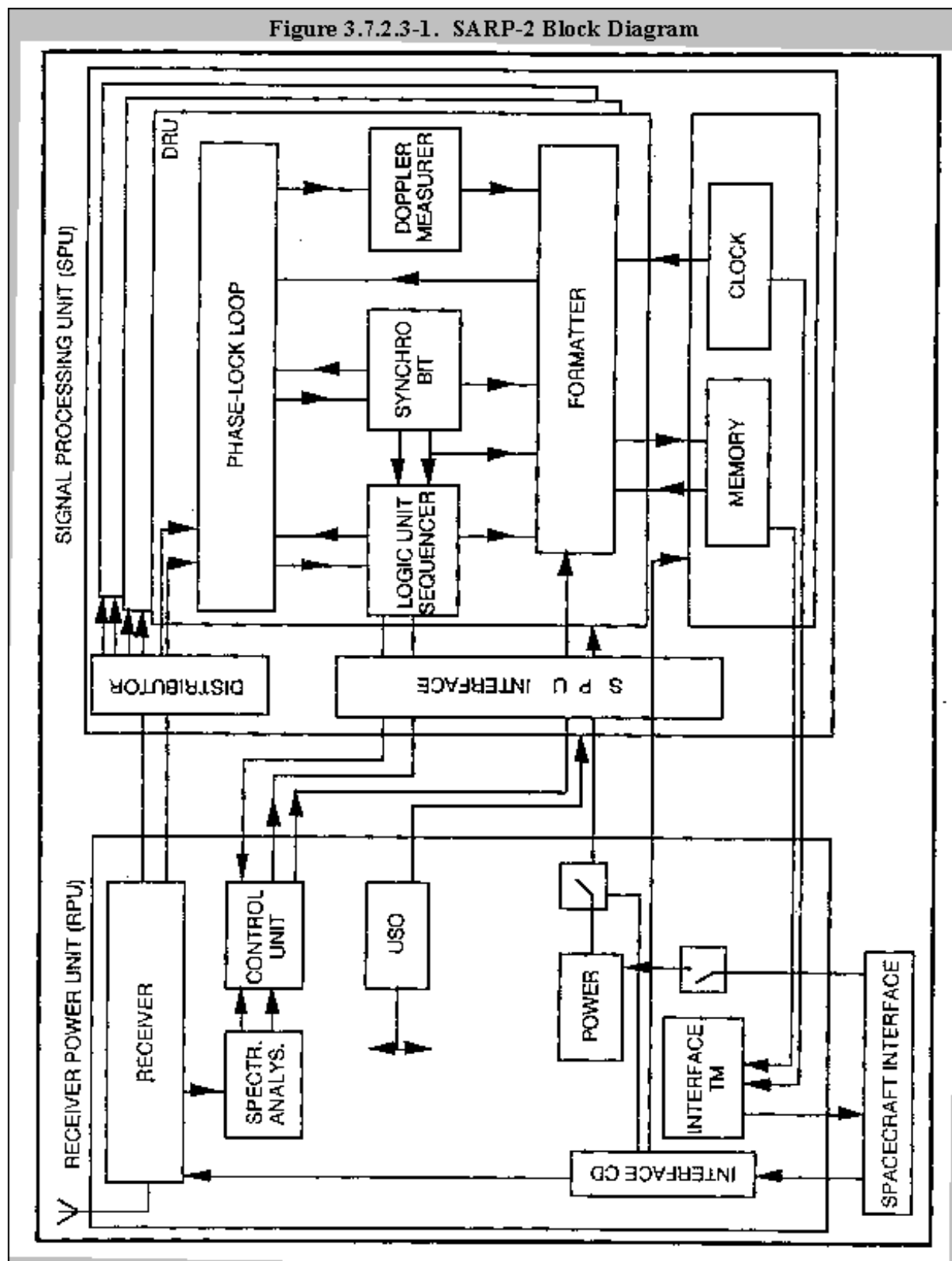
conversion process to translate the signal to a lower frequency. The receiver is a constant gain type, linear over a 23 dB dynamic range.

The signal processing unit (SPU) is a Fast-Fourier Transform which searches the full 80 kHz bandwidth. When a signal is detected, the control unit assigns the signal to a Data Recovery Unit (DRU) on the basis of an algorithm designed to optimize the multiple-access performance. The algorithm for assignment is based on the frequency and level of input to the receiver as well as the current assignment state of the DRUs.

When a signal is assigned to a DRU, the voltage controlled oscillator (VCO) is pre-steered to within the lock-in range by a voltage which is proportional to the signal frequency as determined by the search unit. After VCO lock-up, the signal is demodulated and fed to a bit synchronizer which supplies the clock for subsequent digital processing. When the clock is available, the sync word contained in the message is detected and the remaining digital message processed. Doppler frequency is determined by counting the VCO signal for a specified time base referenced to the processor ultra stable oscillator (USO).

The processor formatter outputs a composite message made up of eight 24-bit words. Messages are organized into either long or short messages depending on the total number of data bits to be transmitted. The expected message length is determined by the processor by detecting a single bit flag indicating message length contained in the received message from the experimental ELT/EPIRB. The formatted message output is sent to the main memory and to the interface unit where it is transferred to the SARR 2.4 kbps input port.

The processor is implemented physically into two units with a total weight of 24.5 kg, and a total volume of 37 liters. Power consumption is 19.9 Watts.

3.7.3   CALIBRATION REQUIREMENTS

The SARR and SARP-2 have no on-orbit calibration requirements.

3.8   SOLAR BACKSCATTER ULTRAVIOLET SPECTRAL RADIOMETER (SBUV/2)

3.8.1   INSTRUMENT OPERATION

3.8.1.1   Purpose of the SBUV Instrument

The purpose of the SBUV instrument is to measure the Solar irradiance and Earth radiance in the near ultraviolet spectrum. From these data, the following atmospheric properties can be deduced:

   1.   The global and vertical distribution of stratospheric ozone

   2.   The structure and dynamics of stratospheric ozone

   3.   Photochemical processes and the influence of "trace" constituents on the ozone layer.

   4.   Long-term solar activity in the Ultraviolet spectrum.

Usable data can only be collected by the SBUV when it is integrated onto an afternoon spacecraft due to solar angle requirements.

3.8.1.2   Instrument Description

Two optical radiometers form the heart of the SBUV instrument: a monochromater and a small but very important Cloud Cover Radiometer (CCR). The instrument contains four mechanisms: a movable grating for wavelength selection in the monochromater, a deployable diffuser which selects solar or Earth radiation measurements, a deployable Mercury lamp for wavelength calibration and an optical chopper mechanism which converts the steady incoming radiation to pulses of UV light which can be readily processed by the SBUV detectors and electronics.

The optical detectors consist of a photo multiplier tube (PMT) in the monochromater and a vacuum photo diode (VPD) in the CCR. The PMT operates from a high voltage supply of about -700 volts DC; the VPD in the CCR operates from a bias of about -10 volts derived from the

instrument's low voltage power supply (LVPS).

3.8.2   SYSTEM DESCRIPTION

The SBUV/2 is a nadir pointing nonspatial scanning instrument sensitive to radiation in the 160 nm to 400 nm ultraviolet spectrum. The overall radiometric resolution is approximately 1 nm in this spectral band.

The SBUV instrument optical hardware and main electronics are carried in two modules. The Sensor Module (SM) contains the optical elements and detectors while the Electronics Module (ELM) houses the main electronics and power supplies.

The use of a deployable diffuser in the SM gives the instrument the versatility of selecting between Solar and Earth measurements. With the diffuser "stowed", the instrument views the Earth directly. The data from this configuration corresponds to Earth radiance. With the diffuser deployed into the "Sun" position, the detector output measurements correspond to solar irradiation data. Ground and in flight calibration data are used to convert the detector data and diffuser mode data to solar irradiation or Earth Radiance units.

The SM houses the monochromater optical hardware which uses a movable grating to select the wavelength where measurements will be made. The grating mechanism can be commanded to any one of 8,192 positions giving the monochromater approximately 0.1 nm wavelength resolution. Commands which correspond to grating positions come from a Read Only Memory (ROM). Data read from the ROM correspond to 12 discrete wavelength positions in the "DISCRETE" mode. In the "SWEEP" mode, the ROM data is simply a grating position corresponding to the wavelength where the sweep will start.

The PMT has a very large dynamic range (greater than 120 dB). This range is transmitted in three ranges requiring a total of 0.75 seconds for stepping and settling of the grating to a new position and 1.25 seconds of integration time before transmission, when the instrument is in this "discrete" grating mode.

In the "sweep" mode, the grating is stepped every 50 ms and the PMT signal is integrated (while the stepping continues) for 100 ms before transmission.

The CCR has a fixed 379 nm filter for wavelength selection and is co-aligned to the monochromater; therefore, it views the same scene as the monochromater. The output of the CCR represents the amount of cloud cover in a scene, as the name implies, and is used to remove the effects of clouds in the monochromater data. CCR data is transmitted once per second in both discrete and sweep modes.

The ELM houses the low voltage power supplies and the electrical (Command and Data) interface to and from the spacecraft.
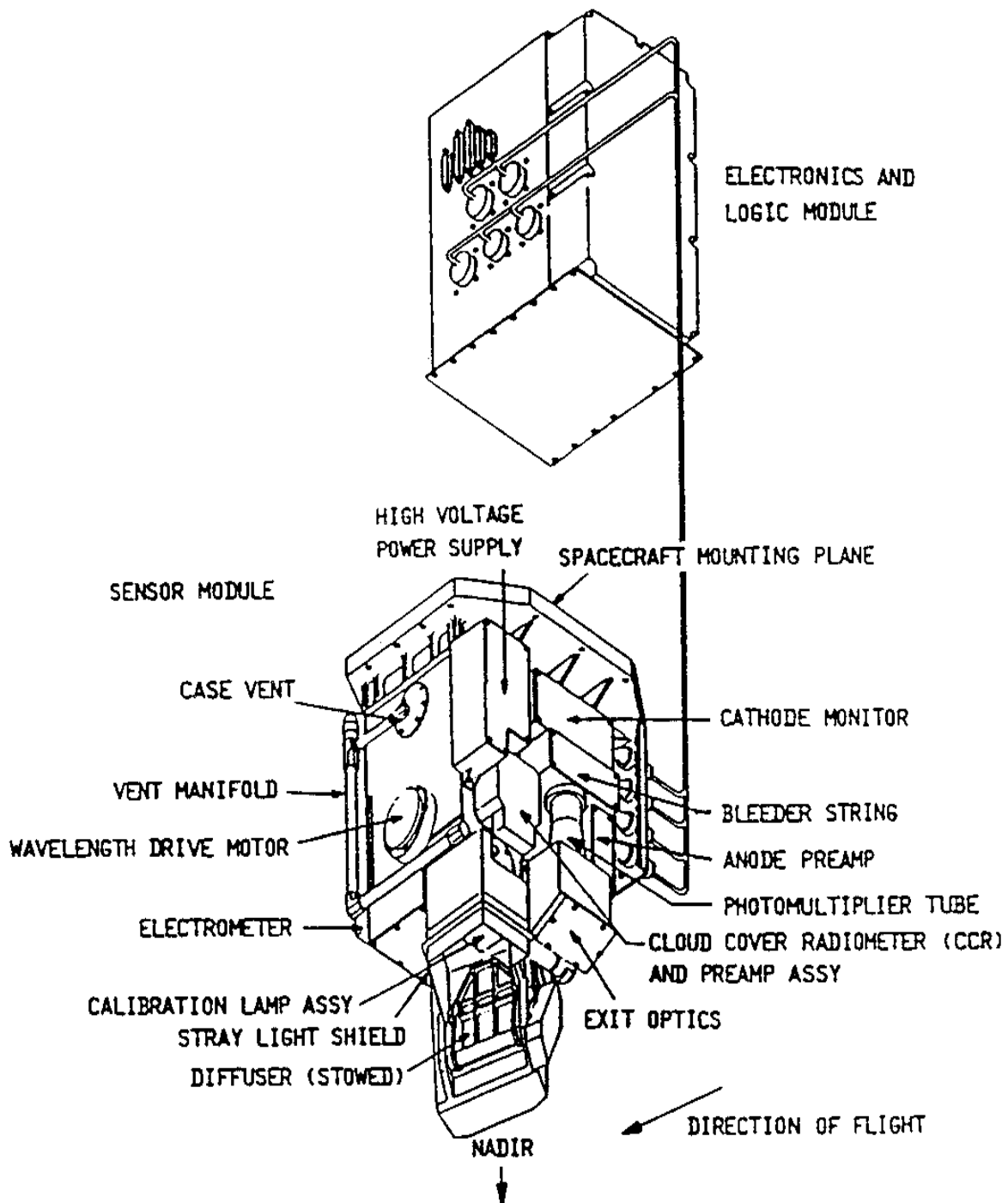
The SBUV/2 mechanical configuration is shown in Figure 3.8.2-1.

3.8.3   CALIBRATION REQUIREMENTS

3.8.3.1   <u>In-Flight Measurement of Detector Gain</u>

The SBUV/2 provides in-flight measurement of changes in gain of the detector(s), including the preamplifier stage. The measurements are sensitive enough to determine a gain change of 0.5% or less

Figure 3.8.2-1. SBUV/2 Instrument.

in the spectral range 300 to 340 nm. Averaging 100 measurements is permissible.

3.8.3.2   In-Flight Wavelength Calibration

The SBUV/2 provides the means of in-flight wavelength calibration. The onboard calibration is sensitive enough to detect 0.1 nm shift in the indicated wavelength with a measurement precision of 0.01 nm.

3.8.3.3   Pre-flight Calibration: Ratio of Radiance to Irradiance Accuracy

The ratio of the radiance calibration to irradiance calibration at the same wavelength is determined to an accuracy of 2.35% in the spectral range 200 nm to 250 nm and to an accuracy of 1.53% at 250 nm; 1.57% at 300 nm and 1.82% in the spectral range 340 nm to 400 nm. The ratio is determined from radiance and irradiance measurements made with a minimum time separation; i.e., at each Discrete Mode wavelength, the spectral drive is stopped and both measurements made before continuing. During the time of ratio measurement, the instrument response does not vary by more than 0.5%.